

# COGNITIVE AND NEURAL SCIENCES DIVISION

## 1989 Programs

AD-A212 634



OFFICE OF NAVAL RESEARCH

Arlington, VA 22217-5000

July 1989

**BEST  
AVAILABLE COPY**

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A1	

This document is issued primarily for the information of U.S. Government scientific personnel and contractor. It is not considered part of the scientific literature and should not be cited as such.

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION: UNLIMITED



# COGNITIVE AND NEURAL SCIENCES DIVISION

## 1989 Programs



**OFFICE OF NAVAL RESEARCH**

**Arlington, VA 22217-5000**

**July 1989**

<b>Accession For</b>	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
<b>A1</b>	

This document is issued primarily for the information of U.S. Government scientific personnel and contractor. It is not considered part of the scientific literature and should not be cited as such.

**APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED**



UNCLASSIFIED  
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b RESTRICTIVE MARKINGS NONE	
2a SECURITY CLASSIFICATION AUTHORITY NOT APPLICABLE		3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; Distribution unlimited	
2b DECLASSIFICATION / DOWNGRADING SCHEDULE NOT APPLICABLE			
4 PERFORMING ORGANIZATION REPORT NUMBER(S)  OCNR 114289-22		5 MONITORING ORGANIZATION REPORT NUMBER(S)	
6a NAME OF PERFORMING ORGANIZATION Office of Naval Research	6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION	
6c ADDRESS (City, State, and ZIP Code) Cognitive & Neural Sciences Division Code 1142 Arlington, VA 22217-5000		7b ADDRESS (City, State, and ZIP Code)	
8a NAME OF FUNDING / SPONSORING ORGANIZATION	8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c ADDRESS (City, State, and ZIP Code)		10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO PROJECT NO TASK NO WORK UNIT ACCESSION NO 61153N	
11 TITLE (Include Security Classification)  COGNITIVE AND NEURAL SCIENCES DIVISION 1989 PROGRAMS (U)			
12 PERSONAL AUTHOR(S) Edited by Dr. Willard S. Vaughan			
13a TYPE OF REPORT Summary	13b TIME COVERED FROM 10/1/88 TO 9/30/89	14 DATE OF REPORT (Year, Month, Day) 89 August	15 PAGE COUNT 267
16 SUPPLEMENTARY NOTATION This is a compilation of abstracts representing R&D sponsored by the ONR Cognitive and Neural Sciences Division.			
17 COSATI CODES FIELD GROUP SUB-GROUP 05 08 05 10		18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number) neural networks attention perception cognition manpower R&D knowledge acquisition man-machine interfaces sensory information processing	
19 ABSTRACT (Continue on reverse if necessary and identify by block number)  This report documents R&D performed by Principal Investigators under the sponsorship of the ONR Cognitive and Neural Sciences Division during fiscal year 1989.			
20 DISTRIBUTION / AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a NAME OF RESPONSIBLE INDIVIDUAL Dr. Willard S. Vaughan		22b TELEPHONE (Include Area Code) (202) 696-4505	22c OFFICE SYMBOL Code 1142

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted  
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE  
UNCLASSIFIED

DTIC  
ELECTE  
SEP 21 1989  
S E D

## FOREWORD

This booklet describes research carried out under sponsorship of the Cognitive and Neural Sciences Division of the Office of Naval Research (ONR) during fiscal year 1989. The Division's research is organized in three programs: Cognitive Science, Perceptual Science and Biological Intelligence. Each program is described by an overview which is followed by thematic clusters of related efforts. Each cluster is described by individual projects which were active during 1989.

This is one of several means by which we communicate and coordinate our efforts with other members of the research-sponsoring and research-performing communities. We encourage your comments about any feature of this booklet or about the programs themselves. If you wish further information, please do not hesitate to contact members of the staff listed in the Introduction. We welcome your interest in our programs and hope that you will continue to keep us informed of related research efforts.

W. S. VAUGHAN, JR.



## CONTENTS

FOREWORD . . . . .	i	
INTRODUCTION . . . . .	v	
COGNITIVE SCIENCE		
The Human Learner: Cognitive Architectures and Abilities . . . . .	1	
Knowledge, Skill and Expertise . . . . .	11	
Learning and Instruction . . . . .	23	
Model-based Measurement . . . . .	45	
PERCEPTUAL SCIENCE		
Vision and Visual Attention . . . . .	61	
Audition . . . . .	87	
Haptics and Sensory Guided Motor Control . . . . .	103	
Human Factors Technology . . . . .	117	
BIOLOGICAL INTELLIGENCE		
Computation in Large Neural Networks . . . . .	131	
Chemical Modulators of Information Processing . . . . .	157	
Neural Processing of Sensory Information . . . . .	169	
Local Neural Circuit Interactions . . . . .	193	
Marine Mammals . . . . .	207	
Behavioral Immunology . . . . .	221	
MANPOWER, PERSONNEL AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM . . . . .		233
INDEX		
Contractors . . . . .	245	
Principal Investigators . . . . .	247	
R&T Project Codes . . . . .	249	

## INTRODUCTION

Cognitive and Neural Sciences Division programs are carried out under contracts and grants awarded on the basis of proposals received in response to a Broad Agency Announcement in the Commerce Business Daily. They are evaluated on the scientific merit of the proposed research, the facilities available for its conduct, the competence of the principal investigators, and relevance to Navy needs. The elements that shape our research program are scientific gaps and opportunities, and operational needs identified in Navy planning documents. Our overall aim is to support quality science for the good of the Navy and the nation.

Cognitive and Neural Sciences programs develop fundamental knowledge about human capabilities and performance characteristics which guide Navy and Marine Corps efforts to improve personnel assessments for selection and classification, training, equipment and system designs for human operation and maintenance. One goal is to provide scientific underpinning for more accurate prediction and enhancement of human performance in training and operational environments. A second goal is to understand the neurobiological constraints and computational capabilities of neural information processing systems for future device implementation. The Division has core programs in cognitive, perceptual and neural sciences which seek to understand human behavior at successively deeper levels of analysis. In addition, several Accelerated Research Initiatives (ARI) are underway which complement and extend research topics of interest to the core programs.

Most of the programs are basic in nature, with a selected augmentation of exploratory development effort. This mix of basic and applied research is developed and managed by the Division staff with the able assistance of the other ONR scientists and with helpful guidance and advice from representatives of various Navy and Marine Corps activities. The programs seek to involve innovative civilian scientists in areas of research relevant to Navy and Marine Corps interests, and by so doing provide new perspectives, new insights, and new approaches to naval manpower, personnel, training, equipment and system design problems. This arrangement provides channels for information to flow back and forth between the civilian research community and the naval community, each keeping the other abreast of new developments. The emphasis is on the creation and exploitation of a cumulative scientific knowledge base upon which new technologies can be developed to improve effectiveness of Navy and Marine Corps men and women.

Continuous efforts are made to coordinate the Division's research program with other ONR Divisions, with in-house Navy Laboratories and Centers, and with the research sponsored by other services and other agencies. We work closely with Technology Area Managers in the Office of Naval Technology

(ONT), and with their Block Managers in Navy Laboratories and Centers to facilitate transitions from basic to applied research.

The Cognitive and Neural Sciences Division is part of the Life Sciences Directorate, which also includes the Biological Sciences Division. Dr. Steven F. Zornetzer is Director of the Life Sciences Directorate, and Commander Charles J. Schlagel is the Deputy Director for Life Sciences.

## DIVISION STAFF

The members of the staff of the Cognitive and Neural Sciences Division are listed below:

DR. W. S. VAUGHAN, JR., DIVISION DIRECTOR  
Telephone: (202) 696-4505

### Cognitive Science Research Programs

Dr. Susan E. Chipman, Program Manager  
Dr. Charles E. Davis  
Dr. Theodore A. Metzler  
Telephone: (202) 696-4318

### Perceptual Science Research Programs

Dr. Harold L. Hawkins, Program Manager  
Dr. John J. O'Hare  
Dr. Teresa A. McMullen  
Telephone: (202) 696-4323

### Biological Intelligence Research Programs

Dr. Joel L. Davis, Program Manager  
Dr. Donald P. Woodward  
Dr. Thomas M. McKenna  
Telephone: (202) 696-4744

In addition to the headquarters personnel listed above, the following psychologist supports the program from the field:

Mr. Gerald S. Malecki  
Office of Naval Research Branch  
223/231 Old Marylebone Road  
London, UK NW1 5TH  
Telephone: 01-409-4471

## COGNITIVE SCIENCE

The Cognitive Science research program of the Office of Naval Research aims to provide a theoretical understanding of the human learner and performer in the domain of complex cognitive skills. This general goal unfolds into several interrelated more specific objectives. First, to provide a theory of the fundamental characteristics of the learner and performer as an information processing system, including a theory of the basis of individual differences in cognitive abilities. Second, to provide a theory of the nature of acquired knowledge and skill involved in performing complex problem-solving and decision-making tasks. Third, to provide a cognitive learning theory that can account for the way in which such complex, structured bodies of knowledge and skill are acquired. Fourth, to provide a precise theory of instruction, founded on cognitive theory, to be used to guide effective education and training of complex cognitive skills such as those involved in performing Naval duties. Finally, this research program aims to provide theoretical foundations for personnel testing and assessment. Research in Cognitive Science is expected to lead to the design of efficient instructional systems across a range of content domains of interest to Navy and Marine Corps training programs, to the development of efficient and accurate computer-based personnel assessment systems, and to the design of expert advisory systems compatible with human intellectual characteristics.

### The Human Learner: Cognitive Architectures and Abilities

Research aimed at discovering and characterizing the stable features of the human learner emphasizes later stages of information processing--cognition rather than perception. This cluster of projects is developing theories for the functional architecture of cognition, including subtheories for memory and elemental cognitive processing operations. Results of research in this cluster will provide sound theoretical bases for personnel testing and selection, and for the individualization of instructional treatments based on accurate diagnosis of cognitive capacities.

### Knowledge, Skill and Expertise

Research on knowledge and expertise aims at formal theories of complex human skill. The program emphasizes the expression of theories in the formal languages provided by mathematics and computer science and includes empirical tests of developed models. Projects target a wide range of complex skills, emphasizing problem-solving and decision-making, so that a general theory can evolve. There is particular interest in understanding the cognitive basis of expertise in making appropriate time-limited decisions in situations characterized by complex and uncertain information. Research results are intended to provide a general model for skill

analysis that can be used to design appropriate training or expert advisory systems.

#### Learning and Instruction

Research on Learning and Instruction aims to produce a knowledge-rich theory of learning that integrates results of work in the prior clusters and develops a coordinated instructional theory that explains how to produce change--learning--in desired directions. Under the Knowledge Acquisition ARI, there is currently a major emphasis on AI-based models of complex human learning. Artificially intelligent, computer-assisted instructional systems as well as more conventional instructional settings are the application areas for the program. Projects are supported which involve either fundamental advances in AI bases for intelligent tutoring or the use of intelligent tutoring systems as a laboratory for investigation into general issues of learning and instruction.

#### Model-based Measurement

Research in this cluster is developing a technology for constructing verifiable empirically-based models of eminent aspects of performance which lead to robust item-level predictions on complex cognitive tasks. For domains for which cognitive science provides detailed qualitative explanations of performance in terms of well-defined mental structures and processes, research is developing a technology for linking task performance to a taxonomy of those structures and processes. This research provides the technology base for improvements to the testing components which constitute the heart of Navy and Marine Corps personnel and training systems in which case-by-case decisions are made. This includes systems for personnel selection and classification, for career counselling, for the design/selection of instructional interventions, for performance aiding, for certification and for performance evaluation. As the Navy modernizes those systems to take advantage of potential improvements in a computer-based workplace, this research is providing the wherewithal for fundamental improvements to those systems through fundamental improvements to their measurement components.

## PERCEPTUAL SCIENCE

Research in the Perceptual Science Program emphasizes issues of perceptual primitives and their representations and transformations in the domains of vision, audition, touch and manipulation, multimodal integration, and the control of motor activity. Research results are expected to transition to Navy and Marine Corps systems in the form of enhanced technologies for human factors engineering, machine vision, acoustic signal classification, adaptive filtering, and dexterous manipulators for autonomous and teleoperated vehicles.

### Vision and Visual Attention

Vision is viewed as a computational process and projects in this cluster emphasize interdisciplinary approaches. Mathematical models are constrained by neurophysiological evidence and tested by psychophysical experiments. Focus is on modeling early, intermediate, and late-visual processes that construct and recognize visual forms and integrate these forms into complex visual representations. A second thrust inquires into the nature of neural mechanisms of control. In their more evolved forms, visual systems contain special modulatory mechanisms that enable them to adjust quickly and adaptively to momentary fluctuations in environmental demand. These are the neural control mechanisms underlying attention and arousal. Interest within this cluster is on empirical research in human visual performance, neuroanatomy, neurophysiology, and neuropsychology aimed at investigation of the control structures and circuitries underlying visual attention, and the neurochemical modulators governing attentional processing.

### Audition

In audition, research projects examine the processing of steady state, transient, and reflected acoustic signals, and model the concurrent processing of complex sound properties and interactions. Current emphasis is on understanding and modeling the classification processes of human listeners, augmented by neurophysiological evidence from other biological species with interesting auditory capabilities and the signal processing capabilities of artificial neural nets.

### Haptics and Sensory Guided Motor Control

Sensory guided motor control is a new area of interest in Perceptual Science. Emphasis is on experimental and theoretical studies of the fundamental issues of coordinated motor function, including the computational bases of force control, and the timing and sequencing of action. Special emphasis is given to work investigating the processes through which sensory information functions as an adaptive guide to coordinated action. Interdisciplinary research is encouraged in psychology, neuroscience, and computer science to achieve

an understanding of sensory guided motor control that will contribute toward enhancement of action adaptability within robotic systems.

The processing of tactile and kinesthetic information in object recognition is a related area of interest in this cluster. Priority research issues include the identification of perceptual primitives, neural network models for tactile processing in somatosensory centers, and perceptual mechanisms that mediate inferential judgments about object properties, classifications and function. Interdisciplinary research is encouraged in psychology, neurophysiology and computer science with the goal of understanding the haptic system in order to provide future robotic devices with intelligent hands.

#### Human Factors Technology

The work described in this cluster constitutes an Exploratory Development project which is designed to extend the basic research program in Perceptual Science toward applications in naval systems. Currently the project consists of applied research in three topic areas: decision making in command and control systems; teleoperated and robotic systems; and acoustic signal analysis. Current work in the command and control area investigates information processing and decision-making in Naval mission planning, airborne ASW, and sonar signal analysis. Work in teleoperation and robotics seeks to develop the conceptual and technical bases for extending human-like sentience and dexterity into previously unattainable and hazardous underwater environments. Work on acoustic signal analysis aims to develop improved techniques for the detection, localization, and classification of active and passive sonar signals.



## BIOLOGICAL INTELLIGENCE

Biological Intelligence programs foster research to elucidate the organization, structural bases, and operational algorithms characterizing information processing networks within neural systems. The goal is to uncover neural architectures and algorithms that can profitably be emulated technologically to yield artificial information processing capabilities of kinds now unique to biological systems. These neural architectures may be derived from either sensory-, motoric- or cognitively-related structures. Overall, the program of research seeks to uncover the organizational principles and operational rules exploited within neural networks to compute intelligent functions, and to emulate these network characteristics within electronic information processing systems.

### Computation in Large Neural Networks

This research examines the global dynamics of biological neural networks composed of large numbers of neurons. The goal of this research is a formal description and simulation of the biological computations underlying information processing, learning and cognition in order to design electronic information processing systems with these network characteristics.

### Chemical Modulators of Information Processing

This cluster of research explores the mechanisms by which neurochemical modulators and neurotransmitters enable neural plasticity, modify information processing, and alter network dynamics.

### Neural Processing of Sensory Information

This research is concerned with the functional organization of sensory neocortex, the computations performed in sensory cortical networks, and the adaptive plasticity of these networks evident at the level of the neuronal receptive fields.

### Local Neural Circuit Interaction

This research advances our understanding of the elements of neural circuits, the individual neurons, by investigating small ensembles of neurons. This research encompasses investigations of the integrative capacities of the dendritic branching structure of neurons, the rules which govern modification of synaptic strength, and the role of membrane electrical properties in information processing and neural plasticity.

## Marine Mammals

An Accelerated Research Initiative, Marine Mammals, investigates a variety of marine mammal capabilities such as detection, localization, recognition, spatial orientation, and communication. The general purpose is to discover underlying principles governing these skill expressions for potential use in both natural and artificial systems.

## Behavioral Immunology

This program is an Accelerated Research Initiative jointly funded by the Biological Sciences and the Cognitive and Neural Sciences Divisions. The program aims at understanding the processes, both biological and psychological, by which life stresses come to influence the functions of the immune system and susceptibility to illness. The projects described are those currently managed by this Division.

**MANPOWER, PERSONNEL AND TRAINING RESEARCH AND  
DEVELOPMENT PROGRAM**

This is an interdisciplinary program of exploratory development managed by Dr. Stanley Collyer in the OCNR Office of Naval Technology. Scientific Officers for these projects are located in the Cognitive and Neural Sciences Division and in the Mathematics Division of the Office of Naval Research. This brochure includes descriptions only for those contracts managed by a Scientific Officer in the Cognitive and Neural Sciences Division.

This program is closely coupled with the operating arms of the Navy and Marine Corps through the mechanism of a planning committee, whose members include ONR Scientific Officers, the Naval Civilian Personnel Command, the Naval Military Personnel Command, the Navy Recruiting Command, the Navy Personnel Research and Development Center, several directorates in the Office of the Chief of Naval Operations, and the Navy Secretariat.

# **COGNITIVE SCIENCE**

## **THE HUMAN LEARNER: COGNITIVE ARCHITECTURES AND ABILITIES**

1/2

**TITLE:** Learning and Individual Differences: An  
Ability/Information-Processing Framework for Skill  
Acquisition

**PRINCIPAL**

**INVESTIGATOR:** Phillip L. Ackerman  
University of Minnesota  
Department of Psychology  
(612) 625-9812

**R&T PROJECT CODE:** 4422543      **CONTRACT No:** N0001489J1974

**CURRENT END DATE:** 31 JUL 1992

**Objective:**

The objective is to investigate the relationship between measures of various psychometric abilities and the course of acquisition of skills of various types: perceptual-motor skills, cognitive skills with minimal perceptual-motor components, and fine motor coordination skills.

**Approach:**

Nine experiments are planned, using appropriately selected skill learning tasks, to examine such questions as the role of cognitive abilities in determining skill transfer, the possibility of changes in measured abilities as a consequence of practice in a skill and the role of various psychometric abilities in determining asymptotic performance. A wide variety of psychometric ability measures will be taken and subjects will undergo prolonged training in order to develop high, asymptotic levels of skill. Tasks studied include variants of a simulated air-traffic control task.

**Progress:**

Drawing upon an extensive body of research literature, Ackerman proposed and tested a theory of the relation between different classes of traditional psychometric ability measures and individual differences in performance during successive phases of skill acquisition. The ability-performance relations have now been shown to generalize from the simple experimental tasks originally used to a more complex simulated air-traffic control task. The effectiveness of different training regimes for individuals of different ability profiles has also been explored.

**Report:**

Ackerman, P. (1988). Determinants of individual differences during skill acquisition: Cognitive abilities and information processing. JEP: General, 117, 288-318.

**TITLE: Functional Architecture of Visual Object Recognition:  
Cognitive Neuropsychological Studies**

**PRINCIPAL**

**INVESTIGATOR:** Martha Farah  
Carnegie-Mellon University  
Department of Psychology  
(412) 268-2789

**R&T PROJECT CODE:** 4422553      **CONTRACT No:** N0001489J3016

**CURRENT END DATE:** 14 NOV 1990

**Objective:**

The objective of this grant is to gain an improved understanding of processes that enable us to recognize objects by sight; i.e., to advance scientific knowledge of the functional architecture of visual object recognition.

**Approach:**

The research will combine theories and methods of cognitive psychology with those of neuropsychology, focussing upon four well-known dissociations and their implications for the functional architecture of normal visual object recognition. In particular, the following dissociations will be examined: recognition vs. localization of visual stimuli, conventional vs. unconventional viewing perspectives, animate vs. inanimate objects, and orthographic vs. nonorthographic objects.

**Progress:**

The PI has completed prior studies that provide information germane to the research this grant will support; for example, the PI has demonstrated clear dissociation between visual mental imagery for the shapes of objects and visual mental imagery for the locations of objects, under an ONR Young Investigator contract N0001486K0094, ending 31 December 1988.

**Report:**

Farah, M. J., Hammond, K. L., Levine, D. N., & Calvanio, R. (1988). Visual and spatial mental imagery: Dissociable systems of representation. Cognitive Psychology, 20, 439-462.

**TITLE:** Brainprints: Computer-Generated Maps of the Human  
Cerebral Cortex In Vivo

**PRINCIPAL**

**INVESTIGATOR:** Michael S. Gazzaniga  
Dartmouth College  
Department of Psychology  
(603) 646-8833

**R&T PROJECT CODE:** 4422557    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 JUN 1990

**Objective:**

The purpose of the work is to further develop computational methodology for converting CAT scan data about human brain damage into a functionally significant mapping onto the computationally "unfolded" surface of the cerebral hemisphere for the purpose of more precisely specifying the relationships between physical damage to the brain and functional consequences for cognitive capacities.

**Approach:**

Computer programs will be developed to further automate the process of converting CAT scan data to a mapping of the "unfolded" surface of the cerebral cortex. The value of this methodology will be investigated in a study of brain damaged patients who show spatial neglect -- an inability to attend to portions of the spatial world around them. The specifics of physical damage will be correlated with the extent and nature of the functional deficits they display. The reliability of the data conversion process will be investigated.

**Progress:**

This contract is new in FY89.

**TITLE:** Computer Based Assessment of Cognitive Abilities

**PRINCIPAL**

**INVESTIGATOR:** Earl B. Hunt  
University of Washington  
Department of Psychology  
(206) 543-8995

**R&T PROJECT CODE:** 4422538    **CONTRACT No:** N0001486C0065

**CURRENT END DATE:** 15 SEP 1990

**Objective:**

The research objective is to conduct studies of individual differences in the ability to coordinate visual-spatial, verbal, auditory, and motor performance, including performance in dynamic tasks, and to determine whether there is an ability to coordinate information received across these modalities that is over and above the ability to deal with each modality separately. Such differences may reflect basic differences in individual cognitive capacities.

**Approach:**

Performance on multi-component tasks requiring coordination of information from multiple sources employing different modalities will be investigated using computer-based presentation and measurement. Carefully designed repeated measures experiments will be complemented by analysis of covariance procedures.

**Progress:**

Studies of the ability to integrate information from several sources clearly demonstrate that there is a distinct ability to integrate visual, verbal, and motor information, separate from the abilities to deal with each of these modalities alone. Sex differences were found in tests dealing with the motions of objects in space. Computerized tasks measuring the ability to orient in large scale space have been developed. In tests measuring attentional performance, about 25% of the variance was found to vary from day to day, but the pattern of high and low performance is not consistent across tasks from day to day. Additional large N studies are planned at the Air Force LAMP facility.

**Report:**

Hunt, E., Pellegrino, J., & Yee, P. (in press). Individual differences in attention. In G.H. Bower (Ed.), Psychology of learning and motivation: advances in research and theory (Vol. 23). New York: Academic Press, 1989.



**TITLE:** Understanding the Immediate Interaction Cycle Using  
the Soar Unified Theory of Cognition

**PRINCIPAL**

**INVESTIGATOR:** Bonnie E. John  
Carnegie-Mellon University  
School of Computer Science  
(412) 268-2000

**R&T PROJECT CODE:** 4422556    **CONTRACT No:** N0001489J1975

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

To extend the Soar model of human cognitive architecture to account for the way in which interaction with perceivable and modifiable displays in the environment -- such as diagrams or computer displays -- serves to augment the limited working memory of human problem solvers and decision makers.

**Approach:**

Videotape protocols with good chronometric data will be collected while people perform tasks which involve constructing and modifying displayed objects on a computer. In addition, at least one non-computerized task, such as the use of a scratch pad while reasoning, will be studied. The information in the videotapes will be the basis for constructing a simulation model of this "immediate interaction cycle" within the Soar theory of cognitive architecture. Integration of display information with internal working memory will be emphasized in this theoretical effort.

**Progress:**

This contract is new in FY89.

**TITLE:** Imagery Processing in the Brain: What Neural Networks Compute

**PRINCIPAL**

**INVESTIGATOR:** Stephen M. Kosslyn  
Harvard College  
Department of Psychology  
(617) 495-3932

**R&T PROJECT CODE:** 4422551 **CONTRACT No:** N0001488RM24006

**CURRENT END DATE:** 09 NOV 1990

**Objective:**

To conduct experimental studies of component processes involved in visual mental imagery, using four different research techniques, to converge on a comprehensive theoretical formulation which relates cognitive functions with their neural-system substrates.

**Approach:**

Studies of visual-imagery component-processing subsystems are conducted with normal observers and in patients with damage to one hemisphere of the brain, using tasks specially designed for these purposes. Brain electrical-activity mapping is employed to obtain convergent evidence for inferences drawn from the other types of data.

**Progress:**

A task battery for the examination of imagery abilities was completed, and pilot testing was initiated on normal observers. A computer simulation model of the subsystems used in high-level vision was developed and it performed 11 types of tasks; the model could be exposed to 41 distinct types of damage and their combinations. The output of the model was a table that indicated which tasks could be performed following a specific type of damage. Predictions from the theory were experimentally tested and showed that qualitatively different types of mental images were produced from each cerebral hemisphere.

**Report:**

Kosslyn, S. M., Sokolov, M. A., & Chen, J. C. (1988). The lateralization of BRIAN: A computational theory and model of visual hemispheric specialization. In D. Klahr & K. Kotovsky (Eds.), Complex information processing comes of age. Hillsdale, NJ: Erlbaum.

**Outside Funding:**

This grant is awarded through and primarily supported by the Air Force Office of Scientific Research.

**TITLE:** Conference on the Functional Imaging of the Human Nervous System

**PRINCIPAL**

**INVESTIGATOR:** Guy M. McKhann  
The Johns Hopkins University  
The Mind/Brain Institute  
(301) 338-8640

**R&T PROJECT CODE:** 4422558    **CONTRACT No:** Not available

**CURRENT END DATE:** 31 JUL 1990

**Objective:**

To conduct a conference to consider how the new technologies for imaging brain activity can best be used to improve understanding of the way in which the brain implements its psychological information processing functions.

**Approach:**

Outstanding researchers familiar with both imaging technologies and the behavioral study of psychological functions will be brought together to discuss these issues.

**Progress:**

This project is new in FY89.

**Outside Funding:**

This award was jointly supported by ONR Code 1142CS and AFOSR.

**TITLE:** Conference on Affect and Flashbulb Memories

**PRINCIPAL**

**INVESTIGATOR:** Eugene Winograd  
Emory University  
Department of Psychology  
(404) 727-7448

**R&T PROJECT CODE:** 4422555    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

The objective of the proposed conference is advancement in scientific understanding of the way in which affective or emotional factors influence psychological processes, such as the storage of information in memory, by examining the psychological phenomenon known as "flashbulb memory." (Recall of the conditions in which one first learned of the John F. Kennedy assassination is a paradigmatic example of this unusually vivid and enduring type of memory.)

**Approach:**

The focus for the proposed conference will be memory research engendered by the explosion of the space shuttle Challenger (on January 28, 1986). Investigators who have been studying subjects' memories concerning this event will meet to (1) compare their findings, (2) discuss the implications of their findings for the relationship between affect and memory, and (3) attempt to devise a common methodology for future research in this area.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

This award was made through AFOSR and jointly supported by ONR Code 1142CS and AFOSR.

**COGNITIVE SCIENCE**

**KNOWLEDGE, SKILL AND EXPERTISE**

11/12

**TITLE:** Artificial Intelligence Measurement System

**PRINCIPAL**

**INVESTIGATOR:** Eva L. Baker  
University of California, Los Angeles  
Center for the Study of Evaluation  
(213) 206-1530

**R&T PROJECT CODE:** 442c022    **CONTRACT No:** N0001486K0395

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

The objective of this contract is to obtain a set of measures appropriate for assessing the performance of AI programs in the areas of natural language understanding, voice recognition, vision, and expert systems.

**Approach:**

Psychometric methods will be refined to permit common scaling of system performance within each area. Specifications for performance at three or more levels of complexity within each area will be prepared. Appropriate test items will be drawn from prior work testing human cognitive capacities. Item analysis techniques will be used to detect significant deviations from patterns of item easiness and difficulty that characterize human performance, in order to detect peculiar limitations of an AI system.

**Progress:**

Entries for the natural language understanding source book are being cross-referenced according to three frames of reference--linguistics, cognitive psychology, and artificial intelligence; release of the deliverable is anticipated by 31 January 1989. Data collection for IRUS, natural language interface, is also in progress, and experiments are being designed to explore the roles of user models in natural language interface evaluation.

**Outside Funding:**

This project is fully funded by DARPA.

**TITLE:** Stability in Conceptual Belief

**PRINCIPAL**

**INVESTIGATOR:** Paul J. Feltovich  
Southern Illinois University at Carbondale  
Department of Medical Education  
(217) 782-7878

**R&T PROJECT CODE:** 4422547    **CONTRACT No:** N0001488K0077

**CURRENT END DATE:** 01 DEC 1989

**Objective:**

Research objectives are to develop a Conceptual Stability Scheme for characterizing misconceptions and for predicting their stability, to apply this Scheme in predicting the stability of misconceptions about the cardiovascular system, to develop a Conceptual Stability Battery for determining the actual stability of each misconception among students, and to create computer network models of selected misconceptions to help account for variation in stability.

**Approach:**

The approach uses a combination of cognitive structure and process analyses based on the Conceptual Stability Scheme, empirical verification of the stability predictions using the Conceptual Stability Battery, and computer network modeling of selected misconceptions. This combination will permit insights into the structure and causes of misconceptions about complex phenomena both through theoretical and empirical studies of skilled human subjects and through manipulations of computer network models of the structures and processes which underlie those misconceptions.

**Progress:**

Materials have been developed for diagnosing the student's belief structure in the domain and for predicting the stability of erroneous conceptual beliefs. Substantial progress has been made in developing the instructional interventions needed for testing the theoretical hypotheses about the stability of (erroneous) belief structures. The diagnostic instrument is also being computerized.

**Report:**

Spiro, R.J., Coulson, R.L., Feltovich, P.J., & Anderson, D.K. (1988). Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains. In The 10th Annual Conference of the Cognitive Science Society. Hillsdale, NJ: Lawrence Erlbaum Associates.

**TITLE:** Analogical Processes and Learning in Physical Domains

**PRINCIPAL**

**INVESTIGATOR:** Dedre Gentner  
University of Illinois  
Department of Psychology  
(217) 333-2186

**R&T PROJECT CODE:** 442f007    **CONTRACT No:** N0001489J1272

**CURRENT END DATE:** 30 NOV 1992

**Objective:**

The goal is to construct and test a general theory of analogical thinking as it occurs in both learning and reasoning. Parametric investigations of the detailed assumptions of the formal model of this theory, the Structure Mapping Engine, will be conducted in order to more precisely specify detailed aspects of the theory. More aspects of the application of the theory will be automated in order to increase its objectivity, and its application to the new and more complex domain of the learning of causal models will be explored.

**Approach:**

Psychological and computational experiments will be conducted in parallel to determine what computational theory can best account for human data on learning, analogy formation, and analogy evaluation. The learning of causal models for physical phenomena in artificial worlds will be an important aspect of the psychological investigations.

**Progress:**

This contract is new in FY89.



**TITLE:** Investigations of Human Question Answering

**PRINCIPAL**

**INVESTIGATOR:** Arthur C. Graesser  
Memphis State University  
Dept. of Psychology & Mathematical Sciences  
(901) 454-2742

**R&T PROJECT CODE:** 4422548     **CONTRACT No:** N0001488K0110

**CURRENT END DATE:** 27 DEC 1989

**Objective:**

This project aims to test, modify, and expand a model of question-answering proposed by Graesser and Clark. The model specifies (1) the information sources tapped during question answering, (2) the symbolic search procedures used to locate information, and (3) the process of converging upon relevant information to be used in generating the answer.

**Approach:**

Psychological experiments will be conducted to test the predictions of the model about the salience, judged quality and latency of production of answers to questions that are asked about narrative texts, expository texts, and general knowledge. Detailed formal representations of the knowledge structures resulting from text reading and comprehension will form the basis of these predictions. Computer simulation models of aspects of the question answering model will be developed.

**Progress:**

A study has been conducted to test a model, QUEST, of the way in which why-questions and how-questions are answered in the context of short narrative passages. Multiple regressions were used to determine the impact of various components of the model upon the quality of the answers produced. The arc search procedure which selects relational paths according to the question type and the constraint propagation mechanism which prunes potential answers contributed more to quality than an intersecting node identifier which detects agreement among different information sources.

**Report:**

Millis, K. K., Morgan, D., & Graesser, A. C. (1988). The influence of knowledge-based inferences on the reading time of expository text. In A. C. Graesser and G. H. Bower (Eds.), The psychology of learning and motivation. New York: Academic Press.

Graesser, A. C., & Franklin, S. (in press). Quest: A cognitive model of question answering. Questioning Exchange.

**TITLE:** Knowledge and Process for Design

**PRINCIPAL**

**INVESTIGATOR:** James G. Greeno  
Leland Stanford Junior University  
School of Education  
(415) 723-0433

**R&T PROJECT CODE:** 4422549    **CONTRACT No:** N0001488K0152

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

The research objective is to conduct studies of the design problem-solving process which will yield data for developing a model that characterizes the contents of the problem space and the problem-solving processes involved in design tasks, focusing on generative processes of formulating and modifying problem goals and plans and on using information from multiple sources.

**Approach:**

The approach uses two kinds of tasks. In one, subjects design instruction, given some goals and constraints. In the other, subjects analyze and evaluate prepared instruction. Empirical studies and psychological experiments will be conducted in which goals and constraints on design problems are manipulated, and in which the availability of knowledge relevant to the design task is varied. Instructional design topics to be studied include training in the operation of artificial devices and academic instruction in statistics.

**Progress:**

An experiment in instructional design has been conducted in which the subjects (Stanford MA students in education) were first instructed themselves about the nature and operation of a pseudo-device. They then designed instruction under two differing conditions -- with the purpose of teaching device operation or with the purpose of using the device to illustrate general principles of energy and machines. Protocols were collected and are being analyzed.

**Report:**

Pirolli, P. L., & Greeno, J. G. (1988). The problem space of instructional design. In J. Psotka, L. D. Massey, and S. A. Mutter (Eds.), Intelligent tutoring systems: Lessons learned. Hillsdale, NJ: Lawrence Erlbaum Associates.

**TITLE:** Explanation and Decision Making in Planning

**PRINCIPAL**

**INVESTIGATOR:** Kristian J. Hammond  
The University of Chicago  
Department of Computer Science  
(312) 702-1571

**R&T PROJECT CODE:** 442f003    **CONTRACT No:** N0001488K0295

**CURRENT END DATE:** 14 NOV 1990

**Objective:**

The objective is to develop a theory of case-based reasoning for problem-solving tasks that addresses questions of memory organization, of decision-making as it applies to the selection of past cases for use in problem-solving, and of the role of explanation formation in learning from case experience.

**Approach:**

Appropriate problem solving domains, such as a simplified bridge design task, will be used as the basis of investigation. An AI program will be developed that constitutes an elaborate hypothesis about the nature of the case-based reasoning process involved in solving such problems. The following major parts to this program are planned: a Problem Anticipator that recalls planning problems in past similar situations, a Case Retriever that searches for a plan that satisfies as many goals as possible while avoiding anticipated problems, a case Modifier that alters the retrieved plan to satisfy additional goals, a Plan Repairer that generates causal explanations for failure and repairs plans on that basis, a Case Storer that indexes plans in memory according to the goals they satisfy and the problems they avoid, and a Blame Assigner that uses causal explanations of failure to identify features to predict and avoid similar failures in the future. Psychological experiments will be used to investigate alternative hypotheses that arise as design issues in the model.

**Progress:**

A program has been developed that can detect blocked problem-solving goals and later recognizes opportunities to reinstate those goals. A case-based reasoner has been developed in the domain of geometric reasoning. Building of a case-based planner in the domain of radiation therapy has begun, with plan memory indexed in terms of visual-pictorial codes.

**Outside Funding:**

This project is jointly supported by ONR Code 1142CS and Code 1133 (Computer Science).

**TITLE:** A Theory of Diagnostic Inference

**PRINCIPAL**

**INVESTIGATOR:** Robin M. Hogarth  
University of Chicago  
Graduate School of Business  
(312) 702-7271

**R&T PROJECT CODE:** 4425080      **CONTRACT No:** N0001484C0018

**CURRENT END DATE:** 14 FEB 1990

**Objective:**

To develop a general theory of diagnostic inference by formulating and testing a model of how causal judgments are made. To develop a theory of evidence about how people judge ambiguous and uncertain data patterns.

**Approach:**

Analytic and experimental efforts are implemented in a combination of theory development, theory representation by models of delineated form, and the formulation of algebraic representations that are consistent with the experimental data.

**Progress:**

An anchoring and adjustment model of judgments of decision weights under ambiguous circumstances was derived from a limited number of behavioral principles; and that model was experimentally supported in the context of two-party conflict decisions. An ambiguity model was developed that provided a good fit to the results of a content analysis of responses made by experts dealing with a series of risks that were correlated rather than independent. Efforts on a contextual theory of risk achieved limited success by focusing on the nature of the interaction between probability and utility in a person's attitude toward risk and ambiguity; the contributions of motivational and cognitive factors to risky decisions were incorporated in the model.

**Report:**

Hogarth, R. M., Gibbs, B. J., McKenzie, C. R. M., & Marquis, M. A. (1989). Learning to make decisions: When incentives help and hinder (Tech. Report). Chicago, IL: University of Chicago.

**TITLE:** Solving Algebra Story Problems

**PRINCIPAL**

**INVESTIGATOR:** Dennis Kibler  
University of California, Irvine  
Department of Computer Science  
(714) 854-5951

**R&T PROJECT CODE:** 442c006    **CONTRACT No:** N0001485K0373

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

The objective is to model the process of solving algebra word problems, including the way in which those processes draw upon multiple sources (types) of knowledge and the use of analogy. It is expected that this will suggest hypotheses about the process of learning such problem solving skills and about the way in which they can be effectively taught in automated tutoring systems.

**Approach:**

Human protocol data are to be collected on a carefully designed set of problems. A computer simulation model of the problem solving process will be built and tested.

**Progress:**

Large numbers of written problem solving protocols were collected on isomorphic pairs of problems and analyzed. Very diverse problem solving process and extensive use of model-based reasoning were revealed. A revised version of the technical report of this phase of the work is expected to be published soon in *Cognition and Instruction*: Hall, Kibler, Wenger, & Truxaw, Exploring the episodic structure of algebra story problems. The computer simulations have now been designed.

**Report:**

Wenger, E. (1987). Artificial intelligence and tutoring systems. Morgan Kaufmann.

Hall, R., Kibler, D., Wenger, E., & Truxaw, C. (1989). Exploring the episodic structure of algebra story problem solving. Cognition and Instruction, 6, 223-283.

**TITLE: Effects of Task Variables on Decision Making Strategies**

**PRINCIPAL**

**INVESTIGATOR:** John W. Payne  
Duke University  
The Fuqua School of Business  
(919) 684-3180

**R&T PROJECT CODE:** 4425063    **CONTRACT No:** N0001480C0114

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

To understand how people adapt their information-processing strategies to the demands of a decision task. To determine the role of time constraints, structure and context of the task, individual differences in effort associated with the task, and perception of its accuracy on decision-making strategies.

**Approach:**

The model of decision-making strategy that was developed and tested during the initial experiments is derived from an effort-accuracy framework and that model will be extended to adaptive decision-making for an editing task. Experiments are conducted to examine the editing process and its determinants; and investigations are made on the display of information, the order of information acquisition, and the role of editing and control aids in these tasks.

**Progress:**

Studies have demonstrated the tradeoff that people pursue in their decision strategies between (a) amount of effort or cognitive resources that are required and (b) the likelihood that the strategy will produce an accurate decision. A componential approach to modeling decision strategies has been successfully developed that decomposes strategies into sets of elementary information processes. The time taken to carry out an elementary process is the measure of effort. This model and its measures were able to predict decision latencies on specific tasks, self-reports of task difficulty, and the errors that occurred in its execution.

**Report:**

Johnson, E. J., Payne, J. W., Schkade, D. A., & Bettman, J. R. (1989). Monitoring information processing and decisions: The mouselab system (Tech. Rep. 89-4). Durham, NC: Duke University. AD A205 963.

Payne, J. W., Bettman, J. R., & Johnson, E. J. 1988. Adaptive strategy selection in decision making. JEP: Learning, Memory and Cognition, 14, 3, 534-552.

**TITLE:** Knowledge and Processes for Design

**PRINCIPAL**

**INVESTIGATOR:** Peter Pirolli

University of California, Berkeley

Department of Education

(415) 652-4560

**R&T PROJECT CODE:** 4422550    **CONTRACT No:** N0001488K0233

**CURRENT END DATE:** 31 DEC 1989

**Objective:**

The research objective is to conduct studies of the design problem-solving process which will yield data for developing a model that characterizes the contents of the problem space and the problem-solving processes involved in design tasks, focusing on generative processes of formulating and modifying problem goals and plans and on using information from multiple sources.

**Approach:**

The approach uses two kinds of tasks. In one, subjects design instruction, given some goals and constraints. In the other, subjects analyze and evaluate prepared instruction. Empirical studies and psychological experiments will be conducted in which goals and constraints on design problems are manipulated, and in which the availability of knowledge relevant to the design task is varied. Instructional design topics to be studied include academic instruction in statistics and training in the operation of an artificial device.

**Progress:**

An initial study of instructional design by statistics professors was completed. Problematic results led to design and execution of a second study of instructional design by professional industrial instructional designers teaching the use of a text-editor. Delivery media available, presumed student background and amount of instruction to be designed were varied. Fine-grained analysis is underway in preparation for a simulation in the SOAR cognitive architecture.

**Report:**

Goel, V., & Pirolli, P. (1988). Motivating the notion of generic design within information processing theory: The design problem space (Report No. DPS-1).

**COGNITIVE SCIENCE**

**LEARNING AND INSTRUCTION**

23/24



**TITLE:** Skill Acquisition in an Intelligent Tutor

**PRINCIPAL**

**INVESTIGATOR:** John R. Anderson  
Carnegie-Mellon University  
Department of Psychology  
(412) 268-2788

**R&T PROJECT CODE:** 442f004    **CONTRACT No:** N0001487K0103

**CURRENT END DATE:** 31 DEC 1989

**Objective:**

The objective of this research is to extend and test a theory of human skill in computer programming, and to use this theory as the student model component of an Intelligent Computer-Assisted Instruction (ICAI) system that is capable of tutoring beginning programmers.

**Approach:**

A specially designed production system (i.e., computer model) was used to model an ideal student being tutored in LISP, a programming language. A "knowledge compilation" or learning feature was added to the production system in order to model both novice and more advanced students accurately. To test predictions from cognitive theory about the learning process, a computerized LISP tutor was constructed that incorporates the following elements: domain-independent tutoring strategies, LISP programming rules for modeling the student, tutorial rules for analyzing student programming code and giving feedback, and practice problems. Experimental tests are in progress.

**Progress:**

Analyses of students' learning of LISP indicate that production rules, and not other plausible descriptive units of behavior, are appropriate units and that the learning of productions follows the power law of learning typical of simple skill acquisition. Individual differences in learning were summarized by differences in individual speed of initial acquisition and of retention of productions, and were not related to particular types or classes of productions. Instructional manipulations such as remediation, content of feedback and timing of feedback had minor effects largely attributable to increased practice. The quality of cognitive task analysis into productions that are to be taught appears to be the most critical variable.

**Report:**

Anderson, J. R., Conrad, F. G., & Corbett, A. T. (in press). Skill acquisition and the LISP tutor. Cognitive Science.

**TITLE:** The Induction of Mental Structures While Learning to Use Symbolic Systems

**PRINCIPAL**

**INVESTIGATOR:** Thomas G. Bever  
University of Rochester  
Department of Psychology  
(716) 275-3213

**R&T PROJECT CODE:** 442f005    **CONTRACT No:** N0001488K0336

**CURRENT END DATE:** 30 APR 1991

**Objective:**

The research objective is to explore the emergence of implicit mental structures (such as linguistic grammars or mental models of machine operations) during the solution of explicit problems. The investigator has proposed a problem-solving theory of the acquisition of implicit structure which he will test with a series of experiments using an artificial symbolic system.

**Approach:**

A series of experiments will be conducted to test hypotheses derived from the investigator's theory of the formation of implicit mental structures during the solution of explicit problems. In addition to attempting to improve the efficiency of the basic paradigm used in a pilot study, the experiments will investigate: implications, for learning, of conflicting regularities within mapping systems for internal perception and production mechanisms; differences between perception and production in learning; and extensions of the paradigm to investigate implications of fuzzy feedback, effects of error messages, and modelling of the acquisition of behavior and structure.

**Progress:**

Four new experiments were run in which the results of the experiments which formed the basis of the proposal were replicated and improved understanding of the conditions necessary to obtain those results was achieved. Computer programs to improve the quality of experimental stimulus presentations have been developed. A preliminary version of a connectionist learning model to account for the results has been developed.

**TITLE:** The Improvement of Text Readability by Phrase-Sensitive Formatting

**PRINCIPAL**

**INVESTIGATOR:** Thomas G. Bever  
University of Rochester  
Department of Psychology  
(716) 275-3213

**R&T PROJECT CODE:** 4428016    **CONTRACT No:** N0001488K0312

**CURRENT END DATE:** 31 MAY 1989

**Objective:**

The research objective is to determine whether text formatted so as to indicate phrase boundaries, using an automated algorithm to determine phrase boundaries, will improve the readability of text.

**Approach:**

Carefully designed experiments with community college subjects, and possibly with Navy recruits or trainees, of different levels of reading ability will be conducted to examine the influences and interactions of several variables on reading speed, comprehension, and retention. The variables include reading ability, text complexity, phrase size, space size, and retention interval; other variables suggested by these experiments may also be studied. The phrase size and space size variables will be controlled by an algorithm for automatically formatting text which has been developed and tested by the PI.

**Progress:**

Several hundred subjects have been tested on phrase structure formatted essay comprehension items. Formatting leads to significantly faster reading and better performance on post-test questions. Effects are largest for below-average readers and difficult essays. A connectionist program has been developed which efficiently approximates the original formatting algorithm and which would generalize to new languages without investment in the development of a new formatting algorithm for that language.

**Outside Funding:**

This project is supported by the Manpower, Personnel and Training Research and Development Program and by NPRDC (6.2 funds).

**TITLE:** Understanding Mechanical Systems Through Computer Animation and Kinematic Imagery

**PRINCIPAL**

**INVESTIGATOR:** Patricia A. Carpenter  
Carnegie-Mellon University  
Department of Psychology  
(412) 268-2091

**R&T PROJECT CODE:** 4428017    **CONTRACT No:** N0001489J1218

**CURRENT END DATE:** 30 NOV 1991

**Objective:**

With computer animations and static diagrams study human processes in the understanding of the kinematics of basic machines and the constraints on those devices. From the experimental results develop models of kinematic imagery that represent mechanical systems. Assess the sources of individual difference in performance on these tasks.

**Approach:**

Experiments will be conducted in which various characteristics of mechanical devices -- such as the complexity of their contours, their motion in depth, or the type of motion conversion involved -- are systematically varied as are features of the display, such as the availability of animation. Records of the subjects eye-movements as they inspect the displays will be kept and the subjects' ability to answer questions about different aspects of device operation will be determined. Computer simulations of the cognitive processes involved will be developed.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

This grant is funded by the Manpower, Personnel and Training Research and Development Program of OCNR (6.2 funds).

**TITLE:** Knowledge Acquisition and Tutoring Based on a Model of Failure-Driven Learning

**PRINCIPAL**

**INVESTIGATOR:** William J. Clancey  
Institute for Research on Learning  
(415) 494-4384

**R&T PROJECT CODE:** 442c028    **CONTRACT No:** N0001489J1526

**CURRENT END DATE:** 14 DEC 1989

**Objective:**

Improve the student modeling and explanation generation capabilities of the GUIDON series of intelligent tutoring programs so that they reflect new theoretical ideas about learning that emphasize the importance of episodes of failure as occasions for learning, provided appropriate explanations are available.

**Approach:**

A general model of the way in which humans reason about problems like medical diagnosis will be used to make inferences about the ways in which student knowledge must be defective in order to account for observed errors. Explanations will be generated which use this diagnosis of the state of student knowledge as a basis for supplying the appropriate missing knowledge. Experimental trials with students will be used to evaluate the quality and effectiveness of explanations.

**Progress:**

This contract is new in FY89.

**TITLE:** Computer Generation of a Tutorial Dialogue

**PRINCIPAL**

**INVESTIGATOR:** Martha Evens  
Illinois Institute of Technology  
Department of Computer Science  
(312) 567-5153

**R&T PROJECT CODE:** 4422554    **CONTRACT No:** N0001489J1952

**CURRENT END DATE:** 31 MAY 1991

**Objective:**

The objective of this grant is to learn how to produce intelligent computer-generated tutorial dialogue.

**Approach:**

The tutorial guidance provided by expert human tutors working with students using an instructional simulation will be recorded and analyzed. The approach to generating text will be similar to that taken by the AI group at U. Mass Amherst -- McKeown, McDonald, and Woolf -- but the Lexical Functional grammar of Kapan and Bresnan will be used with lexical selection based on Even's previous lexical work. In addition, information taken from the student model of the tutoring system will be used to individualize the tutorial dialogue appropriately for student needs.

**Progress:**

This contract is new in FY89.

**TITLE:** Research on Human Tutorial Dialogue

**PRINCIPAL**

**INVESTIGATOR:** Barbara A. Fox  
University of Colorado  
Department of Linguistics  
(303) 492-6305

**R&T PROJECT CODE:** 442c017    **CONTRACT No:** N0001486K0105

**CURRENT END DATE:** 31 DEC 1988

**Objective:**

To test and refine a theory of the processes of human tutorial dialogue, including conversational repair, tutor intervention, and strategies of linguistic communication. The role of each of the following variables will be assessed: mode of communication (face-to-face vs. computer-mediated); subject matter being taught; and the student's level of competence. The proposed theoretical and experimental work will form the basis for improved design principles for natural-language interfaces to intelligent tutoring systems.

**Approach:**

Tutorial interactions at the University of Colorado will be videotaped. Both natural and computer-mediated tutorial dialogues will be recorded. Beginning and intermediate students in LISP-programming and algebra classes will be studied. Face-to-face and computer-mediated modes of communication will be used for different groups of students. A detailed transcript of each dialogue will be made, using a coding system which has been developed in earlier research. These transcripts will be analyzed to determine the effects on dialogue structure of the various conditions of instruction. This analysis will address specific questions concerning communicative trouble and repair, the role of multimedia knowledge representation, and the structure and role of tutorial interventions.

**Progress:**

Four technical reports of progress (listed below) are available, and a book is in preparation.

**Report:**

Fox, B. A. (1988). Cognitive and interactional aspects of correction in tutoring (Tech. Report 88-2). Institute of Cognitive Science: University of Colorado.  
Fox, B. A. (1988). Interaction as a diagnostic resource in tutoring (Tech. Report 88-3). Institute of Cognitive Science: University of Colorado.  
Fox, B. A. (1988). Repair as a factor in interface design (Tech. Report 88-4). Institute of Cognitive Science: University of Colorado.  
Fox, B. A. (1988). Robust learning environments: The issue of canned text (Tech. Report 88-5). Institute of Cognitive Science: University of Colorado.

**TITLE:** Explanation-Based Acquisition of Electronics Knowledge

**PRINCIPAL**

**INVESTIGATOR:** David Kieras  
Regents of the University of Michigan  
Technical Communication Program  
(313) 763-6739

**R&T PROJECT CODE:** 442f002    **CONTRACT No:** N0001488K0133

**CURRENT END DATE:** 31 OCT 1990

**Objective:**

An AI system is constructed for learning electronics concepts from explanatory text and cognitive-psychology experiments on human learning conducted within the same context. Results of the two types of investigations are integrated in the form of a cognitive model that explains human acquisition of knowledge in this domain in terms of the mechanisms in the AI system.

**Approach:**

The system is augmented by additional rules on the behavior of AC circuits in the processing of signals, such as the time structure of the system (history of the previous states of the circuit), multiple events, and representations of the states of the circuit. Learning and schema formation rules are developed from prior rules. The system is implemented in Common LISP. Cognitive models of these processes are developed that provide predictive metrics, and are experimentally evaluated.

**Progress:**

Explanation-based learning principles were used to develop a system which is capable of learning about DC and AC electronic circuits from explanatory texts. The system was given a short explanatory passage and a schematic diagram; and after the system verified the proof, it formed a schema for that class of circuit. When the system attempted to understand another circuit, it instantiated all of the past schemas; this process resulted in faster understanding of the explanation and acquisition of new schema.

**Report:**

Kieras, D. E., & Bovair, S. (in press). Acquiring procedures from text. In R. Barr, M. Kamil, P. Mosenthal, & P. D. Pearson (Eds.), Handbook of reading research. New York: Longman.

Kieras, D. E. (in press). The role of cognitive simulation models in the development of advanced training and testing systems. In N. Frederiksen, R. Glaser, A. M. Lesgold, & M. Shafto (Eds.), Diagnostic monitoring of skill and knowledge acquisition. Hillsdale, NJ: Erlbaum.



**TITLE:** Methodological Foundations for Designing Intelligent  
Computer-Based Training

**PRINCIPAL**

**INVESTIGATOR:** Alan M. Lesgold  
University of Pittsburgh  
Learning Research and Development Center  
(412) 624-7045

**R&T PROJECT CODE:** 442a524    **CONTRACT No:** N0001489J1168

**CURRENT END DATE:** 15 NOV 1989

**Objective:**

This effort will provide support for research and transition of research results in the area of intelligent computer-based training. The objective is to expand and accelerate research in this area and to provide for a uniform mechanism for transition of research results to development projects.

**Approach:**

A network of researchers in the area of intelligent computer-based instruction will be established. The network will include both basic researchers and applied Navy researchers working with a common suite of hardware and software research tools. This effort will provide a communications network for these researchers, develop and maintain a software library, and arrange for meetings as needed.

**Progress:**

Training materials for the Interlisp-D environment have been developed and workshops conducted for the collaborating community of researchers. Software tools, including a general cognitive modeling capability and a highly flexible simulation and interface prototyping tool, Chips, have been developed and made available to other researchers. Explorations of a generalized tutoring architecture have led to advances in both knowledge representation and instructional goal specification. These ideas and tools are being experimentally tested via incorporation in numerous tutoring applications being funded by a variety of sponsors.

**Report:**

Cunningham, R. E., Corbett, J. D., & Bonar, J. G. (1987). Chips: a tool for developing software interfaces interactively (Tech. Rep. UPITT/LRDC/ONR/LSP-4). Pittsburgh, PA: University of Pittsburgh, Learning Research and Development Center.  
Mandl & Lesgold (1988). Learning issues for intelligent tutoring systems. New York: Springer-Verlag.

**TITLE:** Schemas in Mathematics Problem Solving

**PRINCIPAL**

**INVESTIGATOR:** Sandra Marshall  
San Diego State University  
Department of Psychology  
(619) 229-2695

**R&T PROJECT CODE:** 442c010    **CONTRACT No:** N0001485K0661

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

The project objective is to produce a psychological model of the teaching and learning of mathematical problem-solving skills, incorporating three components: a model of knowledge in memory, a model of learning, and a model of instruction. The model of instruction, unlike most, will be explicitly related to the psychological models of learning and memory for this problem domain. It is a test of the value of schema theories of knowledge and skill.

**Approach:**

The underlying semantic structures, or schemas, of mathematics word problems used in school texts, Navy remedial courses, and standardized tests have been analyzed and related to item difficulty in mass test data. Computer simulations of problem-solving knowledge and skill will provide the basis for experimental instruction, and the process of learning will also be modeled in a computer simulation.

**Progress:**

A survey of the types of word problems used in remedial college settings has been completed, confirming that the set of schema representations previously established for the instruction of children also describes the problems presented in adult remedial instruction. The schema theory of problem solving has been formalized, and experimental computer instruction built on that foundation. Instructional experiments have been conducted and data analysis is in process.

**Report:**

Marshall, S. P. (in press). Assessing knowledge structures in mathematics: A cognitive science perspective. In J. Algina & S. Legg, Cognitive assessment of language and mathematics outcomes. Norwood, NJ: Ablex.

Marshall, S. P. (in press). Assessing problem solving: A short-term remedy and a long-term solution. In R. I. Charles & E. A. Silver (Eds.), The teaching and assessing of mathematical problem solving. Hillsdale, NJ: Erlbaum.

**TITLE:** Human Plausible Reasoning and Learning: Development of a Computational Model and a Unified Theory.

**PRINCIPAL**

**INVESTIGATOR:** Ryszard S. Michalski  
George Mason University  
Department of Computer Science  
(703) 323-2713

**R&T PROJECT CODE:** 442f006    **CONTRACT No:** N0001488K0397

**CURRENT END DATE:** 14 MAY 1990

**Objective:**

This research aims to provide computational models of the way in which humans learn and reason with imprecise, incomplete and/or indirectly relevant premises.

**Approach:**

A unified theory of human plausible reasoning and inductive learning will be developed in the form of a computational model. This will build upon the Collins and Michalski "core theory" of human plausible reasoning, upon Michalski's "two-tiered method" for representing flexible context-dependent concepts, and Medin's "multi-criterion patch model" of inductive learning. Further experimental tests of human performance will be conducted in order to test the computational theory against human performance.

**Progress:**

Implementation of a computer model of plausible inference on the Sun computers to be used in the project has been completed. Experimentation with plausible reasoning in the domain of biology is proceeding at BBN with a Symbolics version of the program. The design of tasks for use in related human experimental studies is in progress.

**Report:**

Michalski, R. S. (in press). Two-tiered concept meaning, inferential matching and conceptual cohesiveness. In S. Vosniadou & A. Orton (Eds.), Similarity and analogical reasoning. Cambridge, England: Cambridge University Press.

**TITLE:** Knowledge Based Revision of Cognitive Procedures in  
Response to Changing Task Demands

**PRINCIPAL**

**INVESTIGATOR:** Stellan Ohlsson  
University of Pittsburgh  
Learning Research and Development Center  
(412) 624-7460

**R&T PROJECT CODE:** 442f008    **CONTRACT No:** N0001489J1681

**CURRENT END DATE:** 28 FEB 1991

**Objective:**

The objective is to understand how knowledge of principles in a domain can be used to aid learning and adaptive modification of problem-solving procedures.

**Approach:**

Computer simulations will be built to determine how principled knowledge can be used to monitor, acquire, and adapt procedures. Two domains in which extensive human problem-solving data are available will be explored -- arithmetic and physics problem-solving. Variations in the models will be used to determine how these variations affect the efficiency of learning. In particular, learning mechanisms proposed in various important cognitive theories of learning -- chunking (Newell), knowledge compilation (Anderson) and explanation-based learning (DeJong) -- will be compared for their impact on overall learning performance.

**Progress:**

This contract is new in FY89.

**TITLE:** Impact of Intelligent Computer-Assisted Instruction

**PRINCIPAL**

**INVESTIGATOR:** Janet W. Schofield  
University of Pittsburgh  
Department of Psychology  
(412) 624-3068

**R&T PROJECT CODE:** 442c013      **CONTRACT No:** N0001485K0664

**CURRENT END DATE:** 31 DEC 1991

**Objective:**

The objective of this research is to test a number of theoretically derived hypotheses concerning the impact of the introduction of intelligent computer assisted instruction into a traditional classroom setting. These hypotheses postulate effects on the authority structure of the classroom, the content of the instructor's role, the motivating potential of peer comparison, etc. This research will provide a basis for anticipating and dealing with problems that may arise when intelligent computer instruction is introduced into traditional Navy training settings.

**Approach:**

The research will focus on the first two years of the first practical classroom use of an intelligent computer tutor to teach geometry. Structured observation of both experimental and conventional classrooms will be the primary method of data collection, supplemented by observations of administrative meetings and interviews of participants. Observational records will be stated in concrete, behavioral terms, will be transcribed and entered into a computer data base to facilitate both qualitative and quantitative analyses.

**Progress:**

In the first two years of the project, observations were conducted in the experimental computer tutor classes, in "control" geometry classes, and in two computer science classes. Observations were conducted in other situations of school computer use as well. In addition, extensive interviews with students, teachers, and other project participants were conducted. The observational data have been computerized and analysis is in progress, with a book as the expected final product.

**Report:**

Schofield & Verban (in press). Computer usage in the teaching of mathematics: Issues which need answers. In D. Grouws & T. Cooney (Eds.), Perspectives on research on effective mathematics teaching (Volume 1). Hillsdale, NJ: Lawrence Erlbaum Associates.

**TITLE:** Sixth International Workshop on Machine Learning

**PRINCIPAL**

**INVESTIGATOR:** Alberto M. Segre  
Cornell University  
Department of Computer Science  
(607) 255-9196

**R&T PROJECT CODE:** 433g017    **CONTRACT No:** N0001489J1727

**CURRENT END DATE:** 31 JUL 1989

**Objective:**

The objective is to provide a forum for computer scientists and cognitive psychologists to discuss recent research progress and future directions.

**Approach:**

The Sixth International Workshop on Machine Learning will be hosted by the Department of Computer Science at Cornell University. It will be held 28-30 June 1989. Six to eight separate study sessions, each with 30 - 50 participants, will be held to focus on special topics. Plenary sessions will be held for invited lectures. A Proceedings will be published.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Jointly funded by ONR Code 1133 and the Cognitive Science Program.

**TITLE:** Understanding Stochastic Knowledge Acquisition and Reasoning Using Intelligent Tutoring Methodology

**PRINCIPAL**

**INVESTIGATOR:** Mark E. Siegel  
University of the District of Columbia  
Department of Psychology  
(202) 282-2152

**R&T PROJECT CODE:** dipn130    **CONTRACT No:** N0001489J1245

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

The DOD Defense-University Research Instrumentation Program was designed to improve the capabilities of U.S. universities to conduct DOD-relevant research by supporting the purchase of major equipment critical to the conduct of that research. This effort helps purchase equipment that supports research in the use of intelligent computer assisted instruction to teach quantitative reasoning skills, especially to minority students and trainees.

**Approach:**

The PI will employ software tools for ICAI development produced by other contractors under the Navy Training ARI, and will engage in collaborative research with contractors concerned with the teaching of quantitative skills, in order to explore special issues in the teaching of quantitative skills and statistical reasoning to under-prepared minority students. This equipment is essential to provide access to those tools and instructional software. Instructional experiments will be designed and carried out, with special emphasis on identifying modifications to the instructional approaches and human-computer interaction that may be needed to meet the needs of the target population.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

This grant was supported by the Defense-University Research Instrumentation Program.

**TITLE:** A Proposed Research Center for the Study of  
Intelligent Tutoring Systems in Teaching of  
Quantitative Reasoning

**PRINCIPAL**

**INVESTIGATOR:** Mark Siegel  
University of the District of Columbia  
Department of Psychology  
(202) 282-2152

**R&T PROJECT CODE:** 4422552     **CONTRACT No:** N0001488K0691

**CURRENT END DATE:** 15 AUG 1989

**Objective:**

The potential of existing ICAI software and the possibility of collaborative relationships with other researchers will be explored with the intent of developing an R&D program directed at an instructional approach to improving the quantitative reasoning skills of students in an historically black college as well as skills of similar military trainee populations.

**Approach:**

The PI will obtain existing ICAI software and establish contacts with existing ONR research contractors active in this area. He will review and explore the design and programming of that software and plan a more specified research program for future consideration.

**Progress:**

This contract is new in FY89.



**TITLE:** Tutoring Expertise

**PRINCIPAL**

**INVESTIGATOR:** Elliot Soloway  
Yale University  
Department of Computer Science  
(203) 436-0606

**R&T PROJECT CODE:** 442c007    **CONTRACT No:** N0001482K0714

**CURRENT END DATE:** 15 NOV 1988

**Objective:**

This research will test and refine a theory of the knowledge structures and reasoning processes underlying tutorial expertise in the domain of computer programming. Experimental and computer-based modeling of the diagnostic reasoning of effective human tutors will be used to create principles for the design of more effective intelligent tutoring systems.

**Approach:**

Empirical and computer-simulation methods will be applied to describe the reasoning processes of expert tutors. These reasoning processes will be incorporated into an intelligent computer-assisted instructional system for teaching introductory PASCAL programming. The theory of tutorial expertise will be tested by assessing the success of the automated system in diagnosing and remediating students' misconceptions and systematic programming errors.

**Progress:**

Studies of human tutors have been completed and hypotheses about the process of tutorial planning have been formulated on the basis of data analyses. Construction of the computer simulation program is in process.

**Report:**

Littman, D., Pinto, J., & Soloway, E. (in press). The knowledge required for tutorial planning: An empirical analysis. AI & Education.

**TITLE:** Improvements of the Intelligent Maintenance Training System, with a Second Application

**PRINCIPAL**

**INVESTIGATOR:** Douglas M. Towne  
University of Southern California  
Behavioral Technology Laboratory  
(213) 540-3654

**R&T PROJECT CODE:** 4428011      **CONTRACT No:** N0001487C0489

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

The objective of this contract is to develop an experimental training system for intelligent computer-assisted maintenance training that includes both computer-aided methods for analyzing the practice requirements of maintenance training and a general training system that will provide individualized selection and sequencing of exercises and an automated tutor that will coach students during exercises. This system will incorporate the Navy's existing General Maintenance Training Simulator and will be implemented for Blade Fold Rotor Brake (helicopter) maintenance training.

**Approach:**

Relations among training exercises and required skills will be represented in a database, constructed with computer-aided analyses. Artificial intelligence techniques will be used to model the acquisition of student skills, to select appropriate exercises, to analyze on-going student performance, and to provide appropriate tutorial interventions.

**Progress:**

Implementation of the simulation of parallel analog circuits for the second device implementation of IMTS has been completed. The speed of the fully detailed graphical simulation capability has been improved by a factor of 7, greatly enhancing the interactive instructional capability.

**Report:**

Towne, D. M., & Munro, A. (1988). The intelligent maintenance training system. In J. Psotka, L. D. Massey, & S. A. Mutter (Eds.), Intelligent tutoring systems: Lessons learned. Hillsdale, NJ: Erlbaum.

Towne, D. M., Munro, A., Pizzini, Q. A., Surmon, D. S., & Wogulis, J. (1988). Intelligent maintenance training technology (Tech. Rep. 110). Los Angeles, CA: University of Southern California, Behavioral Technology Laboratories.

**Outside Funding:**

This project has been supported by 6.2 funds from OCNR, NPRDC and AFHRL.

**TITLE:** A Model of Self-Generated Explanation in Skill Acquisition

**PRINCIPAL**

**INVESTIGATOR:** Kurt A. VanLehn  
Carnegie-Mellon University  
Department of Psychology  
(412) 268-4964

**R&T PROJECT CODE:** 442f001     **CONTRACT No:** N0001488K0086

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

A computer-simulation model is produced from the protocols of the problem-solving processes of students who are learning physics problem-solving from example problems in text. It tests the hypothesis and conditions that self-generated explanations of the steps in example problems will permit more effective learning.

**Approach:**

A simulation model is developed that generates sequences of action for solving physics problems, based on protocol data. A simulation program is built with these modules: 1) primitives corresponding to the protocol coding that establish the grain-size of modeling; 2) a non-analogical problem-solver for single-schema (simple) problems; 3) explanation of problem statements that classifies problems appropriately into types; 4) explanation of problem solutions that justifies problem solving actions; 5) analogical problem-solving and learning; and 6) a problem solver for complex multi-schema problems.

**Progress:**

Protocol data from students who solve physics problems using analogical problem-solving and explain the example problems to themselves as they learn, were transcribed, analyzed, and formally encoded. The coding was done in a form that generated data to which a simulation model would be fitted. A vocabulary of 100 formal codes captured the gist of the protocol data.

**Report:**

VanLehn, K. (in press). Learning events in the acquisition of three skills. In G. Olson & E. Smith (Eds.), Proceedings of the Eleventh Annual Conference of the Cognitive Science Society. Hillsdale, NJ: Erlbaum.

**TITLE:** Automating Knowledge Acquisition

**PRINCIPAL**

**INVESTIGATOR:** David C. Wilkins  
University of Illinois Urbana/Champaign  
Department of Computer Science  
(217) 333-2822

**R&T PROJECT CODE:** 433g008    **CONTRACT No:** N0001488K0124

**CURRENT END DATE:** 30 JAN 1990

**Objective:**

The objective is to understand how learning within knowledge based systems can be extended to include the refinement and debugging of knowledge.

**Approach:**

The approach will be to employ learning apprentice strategies which allow a system to acquire meta-level domain knowledge. In addition, the utility of apprentice learning for credit assignment will be assessed, in terms of inferring a knowledge base deficiency (global credit assignment) and isolating deficiencies (local credit assignment).

**Progress:**

Progress has been made in automating explanation-based learning as a means of allowing a system to identify and correct errors in a knowledge base. Traces of human behavior in such activity are compared to independent automated reasoning and differences are explained to allow new knowledge of debugging processes to be acquired.

**Report:**

Wilkins, D. C., (1988). Machine learning techniques for knowledge based systems. Proc. First Scandinavian Conf. on AI, Tromso.

**Outside Funding:**

Jointly funded by ONR Code 1133 and the Cognitive Science Program.

**COGNITIVE SCIENCE**

**MODEL-BASED MEASUREMENT**

45/46

**TITLE:** Conditional Dependence

**PRINCIPAL**

**INVESTIGATOR:** Robert D. Gibbons  
University of Illinois at Chicago  
Department of Psychiatry  
(312) 413-1357

**R&T PROJECT CODE:** 4421553    **CONTRACT No:** N0001489J1104

**CURRENT END DATE:** 30 NOV 1991

**Objective:**

Recently, this investigator used an approximation technique based on the so-called Clark algorithm to obtain estimates of pattern probabilities which are robust to violations of conditional independence. This project is extending that work to new contexts. These include modelling performance on long tests (perhaps 50 items in length), on adaptive tests, on tests scored polychotomously, and on tests composed of several homogeneous subtests.

**Approach:**

Several techniques for estimating the residual covariances will be studied. These include: (a) using the sample tetrachoric correlations, (b) using the expected covariances from a higher dimensional solution, and (c) fitting specific patterned structures (e.g., first-order autocorrelation, block-diagonal, etc.). The viability of these approaches will be studied using simulated and real test data. Finally, a unidimensional polychotomous model for multidimensional data sets will be developed.

**Progress:**

This contract is new in FY89.

**TITLE:** Latent-Trait Representations of Behavioral Data

**PRINCIPAL**

**INVESTIGATOR:** Paul W. Holland  
Educational Testing Service  
(609) 921-9000

**R&T PROJECT CODE:** 4421551     **CONTRACT No:** N0001487K0730

**CURRENT END DATE:** 31 JUL 1990

**Objective:**

One way to view the central problem of item-response theory is the discovery of a parsimonious representation of behavior which reproduces the important features of a data set. The investigator has discovered an identity which appears to linearize that problem for a very general class of models. This project is exploring the ramifications of that identity for item-response theory.

**Approach:**

Numerical studies will examine the viability of representations derived from the Dutch identity in practice. The issue of how large tests must be before first-order approximations are viable will be studied and, the implications of second-order approximations for IRT modelling will be examined.

**Progress:**

Preliminary work is examining how models behave with large numbers of items, the identifiability of parameters, and new ways to assess dimensionality in item-response theory models.

**Report:**

Holland, P. W. (1987). The dutch identity: A new tool for the study of item response theory models (Tech. Rep. 87-78). Princeton, NJ: Educational Testing Service.

**TITLE:** Optimal Design in On-line Item Calibration

**PRINCIPAL**

**INVESTIGATOR:** Douglas H. Jones  
Thatcher Jones Associates, Inc.  
(609) 895-0924

**R&T PROJECT CODE:** 4428007    **CONTRACT No:** N0001487C0696

**CURRENT END DATE:** 30 JUN 1990

**Objective:**

This project is investigating alternatives to the random assignment of items to examinees in item-response-theory calibration studies. The aim is to develop procedures to adaptively gather data on new items. Issues under investigation include: (a) How to incorporate what is known about the unknown abilities in arriving at optimal designs. (b) What sorts of optimality criteria should be used? (c) What to do when "optimal" examinees are not presently available? (d) How might optimal design solutions differ for preliminary item tryout and for fine tuning of the calibrations? (e) Which computational algorithms are most efficient in obtaining optimal designs? (f) How do we set stopping rules and otherwise deal with the fact that we are calibrating multiple items simultaneously? (g) How do we incorporate concerns about model uncertainty and protect against modest departures from the specified model? (h) How do we deal with item-person discordance?

**Approach:**

Theoretical work will extend optimal design theory and develop methods for dealing with model uncertainty. Numerical work will compare the efficiency of numerical algorithms. Experimental work will investigate the issue of item-person discordance.

**Progress:**

Recent progress has occurred in two important areas: First, investigators have formulated an objective function which incorporates uncertainty about examinee abilities (i.e., a design's control variables). Second, investigators have developed and implemented an efficient annealing-like algorithm for maximizing that objective function subject to constraints on the difference between an examinee's ability and the difficulties of the items presented using a penalty-function approach. Results have shown that the annealing algorithm produces exact optimal designs which are more trustworthy than exact designs derived from optimal-approximate designs by rounding fractional values.

**Outside Funding:**

Funds provided by the Manpower, Personnel and Training Research and Development Program.



**TITLE:** Foundations of Formula-Score Theory

**PRINCIPAL**

**INVESTIGATOR:** Michael V. Levine  
University of Illinois at Champaign  
Department of Educational Psychology  
(217) 333-0092

**R&T PROJECT CODE:** 4421546     **CONTRACT No:** N0001486K0482

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

This work is extending Formula Score Theory in several ways: In its present form FST requires that a unidimensional set of "old test" item-response functions are known exactly a priori. This work is reformulating FST to remove that restriction. Present FST density estimation is adequate only for the limited case in which the density is represented as a linear combination of a small number of known functions. This work is exploring alternative approaches to density estimation for the more general case. Current test equating procedures require that the tests being equated measure the same unidimensional ability. This work is formulating an FST approach for equating multidimensional tests.

**Approach:**

Procedures based on initial estimates, followed by iterative cycles of identifying a maximal subset of well estimated items and re-estimating other response functions are being explored. A more general FST is being formulated entirely in terms of characteristics of the joint distribution of observables. Properties of constrained maximum-likelihood estimators are being examined. Unidimensional asymptotic theory is being generalized to the multidimensional case. Ability distribution estimation techniques are being extended to the multidimensional case and will be used to describe the equating function between a multidimensional and a unidimensional test.

**Progress:**

An algebraic approach for discovering the shapes of item-response functions has been developed which, in principle, can recover non-monotonic response functions, even those with multidimensional support. Although preliminary implementations require very large data sets, refinements are under study. In FST item-response functions and densities are characterized by linear combinations of a small number of "basis" functions. A technique for choosing an optimal set of such basis functions has recently been developed.

**Report:**

Drasgow, F., et al, (1987). Modeling incorrect responses to multiple choice items with multilinear formula score theory (Tech. Rep. 87-1). Urbana, IL: University of Illinois, Department of Education-Psychology.

**TITLE:** Polychotomous Measurement for ASVAB

**PRINCIPAL**

**INVESTIGATOR:** Michael V. Levine  
University of Illinois, Urbana/Champaign  
Department of Educational Psychology  
(217) 333-0092

**R&T PROJECT CODE:** 4428020    **CONTRACT No:** N0001489K0059

**CURRENT END DATE:** 14 FEB 1990

**Objective:**

This research is exploring the viability of modelling performance on the Armed Services Vocational Aptitude Battery using polychotomous models. Modelling techniques being examined include (a) the parametric techniques due to Thissen and to Samejima, (b) the new-test/old-test approaches due to Samejima and to Levine, (c) the algebraic formula score approach due to Levine, and (d) the polyweight approach due to Simpson.

**Approach:**

Investigators are following three main lines of attack:  
(a) In certain cases the various approaches to polychotomous modelling are being extended. (b) In other cases they are being integrated. (c) in all cases, empirical comparisons are being made.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funding provided by ONT Manpower, Personnel and Training Research and Development Program.

**TITLE:** Dealing with Uncertainty in Item-Response Theory.

**PRINCIPAL**

**INVESTIGATOR:** Robert J. Mislevy  
Educational Testing Service  
Statistical and Psychometric Research Div.  
(609) 734-1271

**R&T PROJECT CODE:** 4421552    **CONTRACT No:** N0001488K0304

**CURRENT END DATE:** 30 APR 1990

**Objective:**

The work will involve three main tasks: (a) Statistical theory and approximation and computing techniques will be developed for a fully Bayesian approach to item response theory including techniques for obtaining marginal distributions for examinee abilities and item parameters. (b) Difficulties with hyper-variances in hierarchical Bayesian models will be studied. And, (c) theory for drawing inferences from behavior samples within examinees will be developed.

**Approach:**

First, since conjugate priors are not available for IRT applications, investigators will explore a variety of approximations including those proposed by Dunsmore, by Leonard, by Lindley, by Rubin, and by Tierney and Kadane. Second, since data provides virtually no information on hyper-variances and since non-informative priors on hyper-variances are troublesome, investigators will study the influence of moderate priors on posterior results. Finally, investigators will extend their earlier work on drawing inferences from item samples.

**Progress:**

Standard procedures for drawing inferences from complex samples do not apply when the variable of interest can not be observed directly. This is the case for examinee proficiencies in latent-trait applications. In recent work investigators employed Rubin's multiple-imputations approach to approximate sample statistics which would have been obtained, had the latent variable been observable.

**Report:**

Mislevy, R. J. (1988). Randomization-based inferences about latent variables from complex samples (ETS Research Report RR-88-54-ONR).

**TITLE:** Discrete-State Item-Response Models

**PRINCIPAL**

**INVESTIGATOR:** James A. Paulson  
Portland State University  
Department of Psychology  
(503) 464-3923

**R&T PROJECT CODE:** 4421550    **CONTRACT No:** N0001487K0280

**CURRENT END DATE:** 30 APR 1990

**Objective:**

This work is examining new approaches for estimating and validating latent-class models. In previous work, the investigator made effective use of the EM algorithm to estimate these models in unconstrained and in a variety of constrained situations. In this work, he will develop a framework for incorporating a monotonicity constraint when appropriate.

**Approach:**

(a) A test statistic for monotonicity will be developed, and its sampling distribution will be studied. (b) Alternatives to monotonicity will be explored for those situations in which it fails. An approach to be examined early on would add additional states to the model. Partially-ordered hierarchical models will also be examined. (c) Links between these discrete-state models and widely-studied continuous-state models will be examined. In particular, this approach will be compared to the Bock and Aitken approach.

**Progress:**

In general the set optimal statistics for classifying examinees into latent classes is a set of linear formula scores, one for each latent class. However, if certain homogeneity conditions hold, the optimal statistics are unweighted sums of item scores. Recent work examined the cost of using the simpler statistics when those homogeneity conditions are violated.

**TITLE:** Multidimensional Item Response Theory Applied to  
Practical Testing Problems

**PRINCIPAL**

**INVESTIGATOR:** Mark D. Reckase  
American College Testing Program  
Test Development Division  
(319) 337-1000

**R&T PROJECT CODE:** 4421556    **CONTRACT No:** N0001489J1908

**CURRENT END DATE:** 30 APR 1992

**Objective:**

This work is developing a practical item-response theory for multiple-content domains. Issues under study include: (a) calibration of multidimensional item response models, (b) the linking of separate calibrations, (c) equating specific composites, and (d) optimal test design including multidimensional adaptive testing.

**Approach:**

(a) Theoretical and empirical studies will examine the distribution of items and examinees needed to calibrate multidimensional response models and will explore the ramifications of certain criteria for making the calibrations unique. (b) Strategies will be developed for dealing with those situations in which maximum-likelihood estimates of model parameters are infinite. (c) The linking work will explore an extension of the Stocking and Lord procedure. And, (d) empirical studies will compare an equating procedure based on multidimensional models with the standard equipercentile approach.

**Progress:**

This contract is new in FY89.

**TITLE:** Latent-Trait Theory for Polychotomously-Scored Items.

**PRINCIPAL**

**INVESTIGATOR:** Fumiko Samejima  
The University of Tennessee  
Department of Psychology  
(615) 974-6846

**R&T PROJECT CODE:** 4421549    **CONTRACT No:** N0001487K0320

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

The objective of this work is to develop the theoretical foundations for polychotomously-scored test items with non-monotone item-response functions. Included are (a) improvements to modelling techniques, (b) exploration of criteria for response characteristics of items in an ideal item pool, for efficient item selection, and for test termination, (c) development of procedures for describing examinee performance, (d) development of procedures for calibrating items on-line, and (e) development of a framework for assessing item and test validity within an item-response-theory framework.

**Approach:**

(a) The PI's procedures for non-parametric estimation of item-response functions will be extended to the case in which the latent density is badly skewed and to the case in which it is multidimensional. (b) The usefulness of approximations derived from results for multidimensional models of continuous responses will be examined. (c) A variety of ways to conceptualize an item's local validity will be studied. And, (d) results will be implemented in portable computer programs.

**Progress:**

The conditional PDF approach for estimating the operating characteristics of discrete item responses requires the estimation of the conditional distribution of MLE ability estimates given ability. These density estimates have been shown to be biased for extreme abilities. Initial results with a new "differential weight" procedure appear to ameliorate the problem.

**Report:**

Samejima, F. (1988). Information functions for the general model for differential strategies in cognitive processes (Tech. Rep. 88-2). Knoxville, TN: University of Tennessee, Department of Psychology.

**TITLE:** Foundations of Multidimensional Item-Response Theory.

**PRINCIPAL**

**INVESTIGATOR:** William F. Stout  
University of Illinois at Champaign  
Department of Statistics  
(217) 333-6218

**R&T PROJECT CODE:** 4421548    **CONTRACT No:** N0001487K0277

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

This work is further developing the foundations of item response theory for multidimensional data sets. This includes: (a) exploration of the theoretical relationship between a conditional-association notion of dimensionality and Stout's notion of the essential dimensionality of a data set, (b) exploration of the implications of the Suppes and Zanotti Common Causes Theorem for multidimensional IRT modelling, (c) development of a framework for studying issues of test bias based upon the notion of the essential dimensionality of a test, and (d) exploration of alternative dependence structures for multidimensional modelling.

**Approach:**

(a) Stout's notion of the essential dimensionality of a data set is being refined and extended, and the relationship between it and Holland's notion of conditional association is being studied. (b) The notion of test bias is being cast within the essential dimensionality framework in order to gauge when group differences are likely to be troublesome. (c) New notions of the reliability of a test are being explored. And, (d) models based upon sequential dependence structures are being examined.

**Progress:**

Developed a generalization of latent-trait theory based entirely upon monotonicity and a weak notion of dependence. Results have shown that even with this weaker notion of dependence, latent-trait theory retains many of its most important measurement properties.

**Report:**

Stout, W. (1988). A nonparametric multidimensional IRT approach with applications to ability estimation (Tech. Rep. 88). Urbana, IL: University of Illinois, Department of Statistics.

**TITLE:** Improved Scoring for Tests and Criteria

**PRINCIPAL**

**INVESTIGATOR:** James B. Sympson  
Navy Personnel Research and Development Center  
(619) 553-7610

**R&T PROJECT CODE:** 4421554    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 SEP 1991

**Objective:**

Develop new item-selection and performance-modelling techniques which have the potential for increasing the reliability and validity of tests and criteria. Although emphasis will be given to modelling multicategory data, attention will also be given to exploiting information in response times.

**Approach:**

First, Sympson's polyweighting procedures will be compared to IRT-based procedures using both simulation and Navy data. For this purpose, Sympson's Model 8 will be used both as a basis for adaptive item selection and as a component of a new procedure for estimating response pattern probabilities when a test is multidimensional. Second, a new procedure for gauging IRT-model goodness-of-fit will be developed. Third, work on the use of response-time data will examine the viability of separately modelling examinees who answer an item correctly, but with markedly different response times. Finally, work aimed at improving the scaling of criterion measures will explore the viability of polyweighting and polychotomous scoring.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funding provided by ONR Laboratory Participation Program.



**TITLE:** Advancement of the Theory of IRT-Based Error  
Diagnostic Testing

**PRINCIPAL**

**INVESTIGATOR:** Kikumi K. Tatsuoka  
University of Illinois  
Computer-based Education Research Laboratory  
(217) 244-4307

**R&T PROJECT CODE:** 4421557    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 JUN 1992

**Objective:**

The objective of this work is to extend the Rule Space approach to diagnostic testing in three important areas: (a) A coherent approach to test item construction, selection, and evaluation will be developed; (b) a more powerful approach to classifying response patterns will be sought; and (c) techniques for modelling "bug migrations" will be explored.

**Approach:**

(a) The investigator's approach to the item construction/selection issue involves constructing stochastic models of item subtask performance. Her initial approach views item subtasks as known entities. (b) The focus of attention for increasing the power of classification procedures will be on methods which avoid the multivariate Normality assumption employed in discriminant analysis. Methods such as kernel density estimation and the k nearest neighbors method will be explored initially. (c) Work on identifying and modelling "bug migrations" will employ combinatorial analyses of response patterns to detect phase changes.

**Progress:**

This contract is new in FY89.

**TITLE:** A Theory of IRT-Based Diagnostic Testing

**PRINCIPAL**

**INVESTIGATOR:** Kikumi K. Tatsuoka  
University of Illinois at Urbana  
Computer-based Education Research Laboratory  
(217) 244-4307

**R&T PROJECT CODE:** 4422541    **CONTRACT No:** N0001486K0290

**CURRENT END DATE:** 14 APR 1989

**Objective:**

The objective of this work is the further development of the foundations of the rule space framework for diagnosing the misconceptions of trainees from their performance on cognitive tasks.

**Approach:**

(a) Develop a coherent mathematical/statistical theory for rule-space inferences, (b) establish convergence and efficiency properties of adaptive item selection strategies, (c) refine approximations to the so-called "bug distribution", (d) extend the model to deal with polychotomously-scored responses, and (e) investigate the generality of the framework within a Navy training context.

**Progress:**

It is a well-documented fact that when faced with a problem he does not know how to solve, a trainee may exhibit inconsistent behavior. These "bug migrations" are the bane of cognitive diagnosis. Recently, these investigators have developed indices of the stability of rule application. Subsequently, these indices were used to study the dynamics of performance during instruction.

**Report:**

Tatsuoka, K. K. (1988). Stability of rule application (Tech. Report). Urbana, IL: CERL, University of Illinois.

**TITLE:** The Implications of Multidimensionality for  
Item-Response Theory Applications.

**PRINCIPAL**

**INVESTIGATOR:** Ming-mei Wang  
University of Iowa  
Dept. of Psychological-Quantitative Foundation  
(319) 335-5572

**R&T PROJECT CODE:** 4421555     **CONTRACT No:** N0001489J1667

**CURRENT END DATE:** 28 FEB 1992

**Objective:**

This work has three main objectives: (a) to examine the relationship between estimated multidimensional models and their estimated unidimensional counterparts; (b) to develop methods for empirically assessing the "strength" of multidimensionality in terms of the conditional dependencies among items; and (c) to examine the relationship between various sorts of model misspecification and applications like differential item functioning, adaptive testing, and test equating.

**Approach:**

(a) A detailed analysis of the potential causes of differential item functioning and its ramifications for data is being conducted. (b) The effects of multidimensionality on the effects of test equating is being addressed in terms of population differences in test characteristic curves. (c) The relationship between characteristics of a multidimensional item pool and unidimensional adaptive testing is being studied. And, (d) An effective item selection strategy based on estimated multidimensional item response functions is being devised.

**Progress:**

This contract is new in FY89.

**PERCEPTUAL SCIENCE**

**VISION AND VISUAL ATTENTION**

61/62

**TITLE:** Role of Locus Coeruleus Activity in Regulation of Behavioral Responsiveness

**PRINCIPAL**

**INVESTIGATOR:** Gary Aston-Jones  
New York University  
Department of Biology  
(212) 598-3994

**R&T PROJECT CODE:** 4426559     **CONTRACT No:** N0001486K0493

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

The program of research aims to (1) determine what stimulus qualities are sufficient to evoke responses from locus coeruleus (LC) neurons in the absence of explicit S-R contingencies, and (2) determine whether manipulations of the ambient environment or task parameters known to effect human performance in attention tasks alter tonic or phasic aspects of LC discharge.

**Approach:**

Unitary action potentials and field potentials from LC are recorded simultaneously with EEG, EOG, heart rate, and general movement, while animals are performing a variety of attention-demanding vigilance tasks.

**Progress:**

Projections to and from the locus coeruleus, the major source of norepinephrine in the mammalian cortex, have been elaborated. Firing patterns in the LC under varying conditions of stimulation and task demand have been mapped, clarifying the role of this brain stem structure in controlling vigilance and attentional selectivity.

**Report:**

Ennis, M. & Aston-Jones, G. (1988). Excitatory synaptic transmission from paraventricular nucleus to locus coeruleus: A new amino acid pathway in brain. J. Neuroscience, 8, 3644-3657.

**Outside Funding:**

Partial funding for this project was provided by AFOSR.

**TITLE:** Studies of Contour and Surface Segmentation in Monkey  
Striate Cortex Using Voltage Sensitive Dyes

**PRINCIPAL**

**INVESTIGATOR:** Gary G. Blasdel  
Harvard College  
Department of Neurobiology  
(617) 732-1214

**R&T PROJECT CODE:** 442g005    **CONTRACT No:** N0001489J1953

**CURRENT END DATE:** 07 MAY 1992

**Objective:**

The objectives of this research are to: (1) determine the extent to which striate cortex neurons are sensitive to the distinction between contour edges and surface edges, and (2) explore the anatomical and topological organization of striate cortex cell groups categorized on this basis.

**Approach:**

Extracellular single unit recordings in monkey striate cortex will be used to determine response selectivity to surface and contour edges in response to a variety of visual stimuli. Optical imaging with voltage-sensitive dyes will be used to map patterns of cortical activity in response to visual stimuli optimized for distinguishing contour-edge and surface-edge sensitive regions.

**Progress:**

This contract is new in FY89.

**TITLE:** Committee on Vision

**PRINCIPAL**

**INVESTIGATOR:** P. Ebert-Flattau  
National Academy of Sciences  
National Research Council  
(202) 334-2565

**R&T PROJECT CODE:** 4426125    **CONTRACT No:** N0001487K0345

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

Provide information on current and anticipated problems relevant to Navy and other federal agencies in the areas of vision, visual standards, and hazards to vision.

**Approach:**

Working groups will be formed to address specific issues identified by a sponsor. Each group will be made up of leading experts in scientific fields relevant and specific to the problem at hand, and will produce a document responsive to problem solution.

**Progress:**

During the past year the Vision Committee has continued its management of working group activities on key topics, including Myopia prevalence and Progression, Wraparound Visual Displays, and Contact Lens Use Under Adverse Conditions.

**Report:**

Committee on Vision. (1989). Myopia prevalence and progression. Washington, DC: National Academy Press.

**Outside Funding:**

Partial funding for this project was provided by AFOSR, ARI, Department of Veterans Affairs, Naval MRD Command, NASA, NIH-NEI, NIH-NIA, and NSF.

**TITLE:** Using Time-to-Collision to Recover 3-D Motion for Navigation and Manipulation

**PRINCIPAL**

**INVESTIGATOR:** Ellen Hildreth  
Massachusetts Institute of Technology  
Center for Biological Information Processing  
(617) 253-5819

**R&T PROJECT CODE:** 400x053    **CONTRACT No:** N0001488K0607

**CURRENT END DATE:** 24 SEP 1991

**Objective:**

To establish the computational and psychophysical bases for design of networks that have the capacity to compute quickly and accurately the structure and relative motions of environmental objects with which an artificial system may physically interact during the course of navigation and object manipulation.

**Approach:**

Estimates of the time-to-collision with an approaching surface will be used to investigate the recovery of 3-D trajectory of moving targets. The psychophysical findings will be employed as the basis for design of computational models of visually-guided navigation and object manipulation.

**Progress:**

Initial work has addressed algorithms for recovering the 3-D trajectory of an object from its 2-D image motion and removing the components of the image motion field due to rotation of the eye or camera. A trajectory model has been found that combines the local computation of 3-D heading using estimates of time-to-collision and instantaneous velocity with the computation of the 6 global parameters of motion, allowing predictions of future location of a moving object.

**Report:**

Hildreth, E. (1988). Computational studies of the extraction of visual spatial information from binocular and motion cues. Canadian Journal of Physiology and Pharmacology, 66, 464-477.



**TITLE:** Electrophysiological Studies of Visual Selective  
Attention and Resource Allocation

**PRINCIPAL**

**INVESTIGATOR:** Steven A. Hillyard  
University of California, San Diego  
Department of Neurosciences  
(619) 452-3797

**R&T PROJECT CODE:** 4426556    **CONTRACT No:** N0001489J1806

**CURRENT END DATE:** 31 MAY 1992

**Objective:**

To clarify mechanisms of visual-spatial selective attention in humans, both at the level of perceptual processing and at the level of the underlying brain physiology. The focus will be on the effectiveness of different advance cuing procedures for orienting attention to regions of a visual display.

**Approach:**

The indices of attentional orienting to be studied are facilitation of reaction times and enhanced event-related potentials (ERPs) to stimuli at attended locations. The proposed methods will eliminate confounds that have clouded the interpretation of previous studies.

**Progress:**

An extensive series of experiments carried out over the past three years have yielded results consistent with an attentional mechanism of early sensory gating or 'gain control' that is presumably the result of descending neural influences upon the ascending sensory pathways. The location of this selection mechanism appears to be in the extrastriate visual cortical areas 18 and 19.

**Report:**

Magnun, G. R., Hansen, J. C., & Hillyard, S. A. (1989). The spatial orienting of attention: Sensory facilitation or response bias? In R. Johnson (Ed.), Current research in event-related brain potentials. Electroenceph. Clin. Neurophysiol. (Suppl).

**Outside Funding:**

This project was partially supported by AFOSR.

**TITLE:** Electrophysiological Studies of Visual Attention and  
Resource Allocation

**PRINCIPAL**

**INVESTIGATOR:** Steven A. Hillyard  
University of California, San Diego  
Department of Neurosciences  
(619) 534-2385

**R&T PROJECT CODE:** 4424232    **CONTRACT No:** N0001489J1743

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

To evaluate the utility of evoked potential methods for the on-line assessment of operator cognitive states (alertness, attentional focus) during tasks requiring the monitoring of several sources of information.

**Approach:**

An irrelevant probe technique will be used to gain evoked potential data on the cognitive states of operators engaged in complex tasks of the type carried out by Navy sonar operators. This technique has been shown in prior work by the PI to be highly sensitive to levels of alertness and attentional focus (e.g., auditory relative to the visual modality).

**Progress:**

This contract is new in FY89.

**TITLE:** Formal and Psychophysical Investigations of Vision:  
Image Motion and Occluding Contours

**PRINCIPAL**

**INVESTIGATOR:** Donald D. Hoffman  
University of California, Irvine  
Department of Cognitive Sciences  
(714) 856-6795

**R&T PROJECT CODE:** 4424219      **CONTRACT No:** N0001488K0354

**CURRENT END DATE:** 31 JUL 1991

**Objective:**

The objective of the proposed research is to develop and to evaluate both empirically and computationally a formal theory of the mechanisms by which object shape can be inferred from motion and contour occlusion. An additional objective is to implement this theory in neurally plausible computer algorithms.

**Approach:**

The proposed investigation will consist of three integrated thrusts: (1) the development of formal theories of shape from motion and shape from occluding contours, (2) the testing of these theories by psychophysical experiments, and (3) the implementation of these theories in neurally plausible computer algorithms.

**Progress:**

Elements of a formal model of processes by which the visual system infers shape from motion were developed and evaluated empirically.

**Report:**

Bennett, B. M., Hoffman, D. D., & Prakash, C. (1989).  
Observer mechanics: A formal theory of perception. San Diego,  
CA: Academic Press.

**TITLE:** Analog Neuronal Networks for Early Vision

**PRINCIPAL**

**INVESTIGATOR:** Christof Koch  
California Institute of Technology  
Computation and Neural Systems  
(818) 356-6855

**R&T PROJECT CODE:** 400x038    **CONTRACT No:** N0001487K0519

**CURRENT END DATE:** 30 JUN 1990

**Objective:**

Objective is to develop theoretical models of computation for early visual processes toward analog VLSI chips for use in robotic vision systems.

**Approach:**

Approach is to simulate analog algorithms for vision on a hypercube computer in two stages; first as independent, then as integrated, processes. Explore design possibilities for silicon implementation.

**Progress:**

An algorithm was developed that uses motion discontinuities to segregate the optical flow field. The algorithm finds those locations at which the motion field changes abruptly and prevents smoothing across these boundaries. The algorithm is implemented on a parallel architecture HYPERCUBE computer. Current work is toward implementation of the algorithm in a resistive network.

**Report:**

Hutchinson, J., Koch, C., Luo, J., & Mead, C. (1988).  
Computing motion using analog and binary resistive networks.  
IEEE Computer, 21, 52-64.

**TITLE:** Control of the Minds Eye: The Dynamics of the  
Distribution of Visual Attention

**PRINCIPAL**

**INVESTIGATOR:** Arthur F. Kramer  
University of Illinois  
Department of Psychology  
(217) 333-9532

**R&T PROJECT CODE:** 4424228      **CONTRACT No:** N0001489J1493

**CURRENT END DATE:** 31 DEC 1991

**Objective:**

The objective is to develop an empirically based model of visual selective attention which describes, at multiple levels of representation, the control of the allocation of attention in visual space.

**Approach:**

Interference in response speed and accuracy produced by visual distractors will be used as an index to investigate a number of critical issues related to the computational properties of visual-spatial attention. Included among these issues are the following: (1) the minimal visual angle or focus of attention in which all events must be processed; (2) the information processing level(s) at which noise stimuli of various types operate to degrade performance; and (3) the effects of training on the ability of performers to adaptively filter unwanted components of a visual scene.

**Progress:**

This contract is new in FY89.

**TITLE:** Investigation of Spread of Attention in the Visual Field

**PRINCIPAL**

**INVESTIGATOR:** David La Berge  
University of California, Irvine  
Department of Cognitive Sciences  
(714) 856-6802

**R&T PROJECT CODE:** 4424208    **CONTRACT No:** N0001488K0088

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

The objective is to test and elaborate a gradient theory of visual-spatial attention. Evaluation of the theory will be based on empirical research and computer simulation.

**Approach:**

An extensive series of experiments will be carried out to analyze the 'width of attentional focus' effect, on which the theory of attention is based, to explore methods to produce and sustain a focus of a given size, and to determine ways in which the focus-width effect can be exploited to optimize human performance in tasks involving object recognition.

**Progress:**

A series of experiments have been completed which establish experimental determinants of the extent, in degrees of visual angle, of the spread of attention across the visual field. Studies with positron emission tomography have identified a thalamic structure, the pulvinar, as playing a critical role in determining the locus and spread of visual attention.

**Report:**

La Berge, D., & Brown, V. (1989). Theory of attentional operations in shape identification. Psychological Review, 96, 101-124.

**TITLE:** Conference on the Perception of Structure

**PRINCIPAL**

**INVESTIGATOR:** Gregory R. Lockhead  
Duke University  
Department of Psychology  
(919) 684-2805

**R&T PROJECT CODE:** 4424231    **CONTRACT No:** N0001489J1888

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

To integrate recent work on the role of assumed or inferred subsets in the understanding of perceptual and cognitive processes. To edit the presentations of a conference on that topic for publication in a commercial book. To bring together the relevant work of active investigators in diverse fields by an invitational conference with discussants who are also expert in those areas.

**Approach:**

Active investigators in diverse fields who are contributing to an understanding of the perceptual and cognitive processes that mediate the use of assumed or inferred subsets of knowledge are invited to a 2-day conference along with an equal number of discussants. A review board has been assembled to edit the papers presented and to prepare them for publication as a book with a commercial publisher. Graduate and postdoctoral students interested in this field are invited to attend.

**Progress:**

Two themes from the research of W. R. Garner were emphasized during the Conference for their contribution to diverse areas of psychology: (a) converging operations, and (b) the distinction between integral and separable attributes. The areas that were examined included: perception, stimulus attributes, language, animal behavior, randomness, attention, and perceptual organization. The twenty papers will be published in 1990 by the American Psychological Association.

**Outside Funding:**

Partial funding provided by AFOSR.

**TITLE:** Physiology of Selective Attention

**PRINCIPAL**

**INVESTIGATOR:** Harold E. Pashler  
University of California, San Diego  
Department of Psychology  
(619) 534-3974

**R&T PROJECT CODE:** 4424212      **CONTRACT No:** N0001488K0281

**CURRENT END DATE:** 31 JAN 1991

**Objective:**

The objectives are to better characterize the mechanisms whereby primates selectively attend to stimuli that are relevant, while ignoring irrelevant stimuli.

**Approach:**

Both human participants and macaque monkeys will be studied under similar task conditions. Psychophysical measures will be obtained from both subject types, and carefully controlled physiological measures of attention-related neural activity in cortical and sub-cortical structures will be obtained in the monkeys studied.

**Progress:**

Studies on both humans and monkeys are in progress. Studies on humans are aimed at determining the relation of learning processes to attention. One completed study has shown that when multiple targets are present, the ability to learn properties of a target is influenced by whether or not the target is attended to. Experiments to determine the effects of distracters on the ability of attention to prime learning are also being carried out. In addition a task is being designed to study the role of space as a mediator for attentional effects. A comparative study in humans and monkeys on the effects of practice on reaction-time speed-up is ongoing. Studies in monkeys of single unit response pattern correlates to the above effects are just beginning. Studies of the effects of hippocampal lesions in monkeys on performance in the reaction time experiments are also just beginning.



**TITLE:** Visual Integration and Recognition

**PRINCIPAL**

**INVESTIGATOR:** Tomaso A. Poggio  
Massachusetts Institute of Technology  
Center for Biological Information Processing  
(617) 253-5230

**R&T PROJECT CODE:** 442g002    **CONTRACT No:** N0001488K0164

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

Objective is to specify biologically plausible implementation models for visual integration and recognition.

**Approach:**

Approach is an interdisciplinary collaboration in computation, psychophysics and physiology. Theoretical and computational studies examine the information processing tasks involved in visual integration and recognition. Algorithms are developed and tested on a parallel supercomputer. Computational work guides design of experiments in human and monkey psychophysics. The physiology examines the neural implementation of integration and recognition tasks in primate cortex.

**Progress:**

Multicue integration in vision is modeled as coupled Markov Random Field lattices; a pair of lattices for each cue, one representing the continuous process and the other the discontinuities (for depth, motion, texture, etc.) Various pairs have been implemented on a 16K processor Connection Machine; integrating edges with stereo, edges with motion, edges with texture. Image analysis is improved over serial implementation of feature-extracting algorithms. Psychological experiments have been conducted to explore effectiveness of various cue combinations on perceived depth.

**Report:**

Poggio, T., Gamble, E., & Little, J. (1988). Parallel integration of vision modules. Science, 242, 436-440.

**TITLE:** Structure and Function of an Attentional System

**PRINCIPAL**

**INVESTIGATOR:** Michael I. Posner  
Washington University  
Anatomy Department  
(314) 362-3317

**R&T PROJECT CODE:** 442a554    **CONTRACT No:** N0001486K0289

**CURRENT END DATE:** 30 APR 1989

**Objective:**

The objective is to develop a better understanding of the role of attention in the execution of a wide variety of cognitive skills and a way of specifying the consequences of deficits in various parts of the neural machinery underlying attentional performance.

**Approach:**

The major methodologies to be employed to identify the function and neuroanatomical loci of the elementary operations underlying attentional behavior include (1) performance studies of normal persons, (2) the use of selected neurological cases with specified lesions in brain areas believed to perform the computations underlying attention, (3) measurement of event-related potentials produced in normal persons and neurological patients engaged in attentional tasks, and (4) studies of cerebral blood flow in normals and patients engaged in attentional tasks.

**Progress:**

The following was accomplished during the past funding period: (1) The relative contributions and specific roles of the posterior parietal cortex, the pulvinar, and the superior colliculus in determining the orientation and action of visual attention were clarified. (2) Using PET methodology, the brain locus of a representative range of cognitive operations was identified.

**Report:**

Posner, M. I., Petersen, S. E., Fox, P. T., & Raichle, M. E. (1988). Localization of cognitive functions in the human brain. Science, 240, 1627-1631.

**TITLE:** Functions of Identified Neural Areas in Selective Attention

**PRINCIPAL**

**INVESTIGATOR:** Michael I. Posner  
University of Oregon  
Department of Psychology  
(503) 686-3186

**R&T PROJECT CODE:** 4424233     **CONTRACT No:** N0001489J3013

**CURRENT END DATE:** 31 MAY 1992

**Objective:**

The objective is to understand general principles underlying the regulation of data processing in the brain by the attentional system. Two major ideas emerging from the PI's earlier work are to be evaluated: (1) the attentional system is functionally and anatomically distinct from the data collection and execution systems on which it operates; and (2) the attentional system is defined as a set of interconnected posterior and anterior brain areas that taken together select information for focal processing.

**Approach:**

The approach entails the use of both behavioral (reaction time) and neuroscientific (evoked potential) techniques to investigate the relation between attention and data collection systems in the human brain. Evoked potential measures will be used to track patterns of attentional activation progressing from anterior (midline anterior cingulate to supplementary motor area) to posterior (parietal and temporal) attentional structures following the cuing of likely target locations.

**Progress:**

This contract is new in FY89.

**TITLE:** A Rodent Model to Identify Brain Structures Involved  
in the Process of Stimulus Recognition

**PRINCIPAL**

**INVESTIGATOR:** Lawrence A. Rothblat  
George Washington University  
Psychology Department  
(202) 994-6809

**R&T PROJECT CODE:** 4424210    **CONTRACT No:** N0001488K0227

**CURRENT END DATE:** 31 JAN 1991

**Objective:**

The objective is to develop a rodent model system for investigation of the role of limbic system structures, including the hippocampus, the amygdala, and the rhinal cortical structures, in the memory and recognition of visual objects and their spatial locations.

**Approach:**

Lesion and tracer techniques will be used to examine the role in stimulus recognition of a variety of limbic system structures, including the hippocampus, amygdala, and rhinal cortex. The effects of controlled lesions will be assessed behaviorally and verified histologically.

**Progress:**

Rats have been trained on two behavioral tasks: the delayed nonmatching-to-sample task, and a concurrent discrimination task. On the concurrent discrimination task, only visual cues are being used. These tasks are behaviorally and methodologically similar to those used to test mnemonic function in monkeys. On the concurrent discrimination task, which is a measure of inferotemporal cortex and hippocampus function in monkeys, rat performance is severely impaired after ventral-temporal lesions. Performance of rats is not impaired after these lesions, however, on the delayed nonmatching-to-sample task. The next steps will be first to confirm these results with more animals and then to examine effects of more limited lesions.

**TITLE:** Brain Communication Theory, Attention and Automaticity

**PRINCIPAL**

**INVESTIGATOR:** Walter Schneider  
University of Pittsburgh  
Learning Research and Development Center  
(412) 624-7061

**R&T PROJECT CODE:** 4424901    **CONTRACT No:** N0001487K0397

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

The objective is to carry out behavioral studies with humans and neurophysiological research with monkeys to assess the nature and anatomical locus of the brain mechanisms underlying visual attention, and the functional changes in these mechanisms that occur during learning.

**Approach:**

Data will be taken from human participants engaged in a variety of tasks that require visual attention. The task parameters found to be effective within humans in modifying attentional function through experience will be employed with monkeys. Single unit recordings of neural activity in several visual information processing structures (V4, IT, pulvinar, frontal eye fields) will be taken from the monkeys, while engaged in the attentional tasks. These data will be used to assess where attentional effects occur in the visual system and how these effects change with learning.

**Progress:**

The project has developed the basic paradigms for testing brain mechanisms involved in directed attention. The work is evaluating controlled and automatic processing architectures for attentional processing and brain communication. The predictions of a simulation model are being evaluated in animal, human, and computer studies.

**TITLE:** The Role of Attention in Visual Processing

**PRINCIPAL**

**INVESTIGATOR:** Gordon L. Shulman  
Washington University  
Department of Neurology  
(314) 362-7170

**R&T PROJECT CODE:** 4424229    **CONTRACT No:** N0001489J1426

**CURRENT END DATE:** 31 MAR 1992

**Objective:**

The objective is to identify the anatomical loci of a variety of attentional effects in vision which have not been investigated on a systematic basis. Both spatial and non-spatial attentional effects will be studied, using sensory adaptation as the vehicle for identifying attentional influences.

**Approach:**

Sensory adaptation and sensory learning effects will be investigated in the presence and absence of focused attention. Since the anatomical loci of the adaptation effects studied have been established, it is possible by this means to isolate the anatomical loci of attentional effects in the visual information processing sequence.

**Progress:**

This contract is new in FY89.

**TITLE:** Visual Attention and Short-Term Memory

**PRINCIPAL**

**INVESTIGATOR:** George Sperling  
New York University  
Department of Psychology  
(212) 998-7868

**R&T PROJECT CODE:** 4424221    **CONTRACT No:** N0001488K0569

**CURRENT END DATE:** 14 JUL 1991

**Objective:**

The objective of the proposed project is to develop formal quantitative descriptions of the mechanisms by which attentional modulation and control structures determine the perception of visual events, and to incorporate these descriptions into a theoretical treatment of human information processing and the sources of its limitations.

**Approach:**

The proposed project incorporates both psychophysical and computational analyses to generate the empirical basis for and computational evaluation of a formal theory of the role of attention in the analysis of visual sensory input.

**Progress:**

Experiments were carried out to investigate information transfer from iconic memory to durable storage. Participants were required to report only part of a visual stimulus consisting of an array of letters, when there was also a post-stimulus visual masker. Results provided evidence for algebraic addition of information transferred from a selective and non-selective process. A simple model extracts the underlying decay function of iconic memory.

**Report:**

Sperling, G., & Gegenfurtner, K. (1988). Two transfer processes in iconic memory. In Proceedings of the 29th Annual Meeting of the Psychonomic Society. Austin, TX: Psychonomic Society.

**TITLE:** Integrating Spatial Information

**PRINCIPAL**

**INVESTIGATOR:** Kent A. Stevens  
University of Oregon  
Department of Computer and Information Science  
(503) 686-4430

**R&T PROJECT CODE:** 4424206    **CONTRACT No:** N0001487K0321

**CURRENT END DATE:** 14 MAY 1990

**Objective:**

To develop a theory of 3-D form perception based on an assumption of two independent representation systems for distance information: (a) absolute distance; and (b) local object-referenced depth relations.

**Approach:**

Theoretical analysis, computational modeling and psychophysical experimentation are utilized to determine the nature of surface topographic features, their interactions, and how the perception of 3D depth arises from those local features.

**Progress:**

Apparent depth in stereograms was shown to exhibit simultaneous-contrast and induction effects similar to those that occur in the luminance domain. These results suggested that stereo depth, like brightness, is reconstructed or recovered from spatial differences, and that both involve the detection of discontinuities, such as edges and borders.

**Report:**

Stevens, K. A., & Brookes, A. (1988). Integrating stereopsis with monocular interpretations of planar surfaces. Vision Research, 28, 371-386.



**TITLE:** Spatial Visual Attention

**PRINCIPAL**

**INVESTIGATOR:** Ronald J. Tusa  
The Johns Hopkins University  
Department of Neurology  
(301) 955-1229

**R&T PROJECT CODE:** 4424211    **CONTRACT No:** N0001488K0280

**CURRENT END DATE:** 30 JUN 1990

**Objective:**

To elucidate the role of the posterior parietal cortex in controlling and maintaining the focus of visual/spatial attention, and specifically to determine whether visual attention is craniotopic or somatotopic and whether it has a directional or a representational organization.

**Approach:**

Rhesus monkeys and human patients with cortical, sub-cortical lesions and callosal sections will be studied in a variety of attentional tasks requiring the participant to focus attention in either the contra- or ipsilesional visual field. The effects of various lesions will be determined both physiologically and behaviorally.

**Progress:**

Several experiments have been completed, and the results show clear evidence for a spatiotopic organization of attentional modulation in the primate posterior parietal cortex. Work has begun to examine the anatomical connections between attentionally active parietal areas and thalamic areas known also to be involved in attentional modulation of visual information processing.

**TITLE:** Integrated Computational Models of Perceptual Performance

**PRINCIPAL**

**INVESTIGATOR:** William R. Uttal  
Arizona State University  
Department of Psychology  
(602) 965-3326

**R&T PROJECT CODE:** 4429011    **CONTRACT No:** N0001488K0603

**CURRENT END DATE:** 31 JUL 1990

**Objective:**

To develop and test a software system for the integration of existing algorithms for computing the detection, localization, and classification of objects in the 3-D world. To evaluate the utility of the resulting system as a test bed for the evaluation of computational algorithms yet to be developed.

**Approach:**

To collect and integrate a collection of individual computational algorithms into a coherent software system capable of simulating the performance of a 'swimmer' that is required to detect and recognize regular geometrical objects, locate them in 3-D space, and then navigate toward them.

**Progress:**

A phase I model is operating in which all the components have been simulated. These functional modules have been integrated into a single operating system. The simulated system is capable of detecting two dimensional objects, segmenting them from their background, recognizing them, distinguishing between objects of different shapes, and assigning spatial locations to them.

**Report:**

Uttal, W. R., Davis, N., Welke, C., & Kakarala, R. (1988). The reconstruction of static visual forms from sparse dotted samples. Perception & Psychophysics, 43, 223-241.

**TITLE:** Neural Models of the Visual Cortex in Information Processing

**PRINCIPAL**

**INVESTIGATOR:** David C. Van Essen  
California Institute of Technology  
Biology Division  
(818) 356-6823

**R&T PROJECT CODE:** 4425083      **CONTRACT No:** N0001489J1192

**CURRENT END DATE:** 30 NOV 1991

**Objective:**

Objective is to determine how information about motion, texture and depth is represented and transformed in early stages of visual processing. Emphasis is on recognition of complex visual forms viewed by task oriented humans and primates.

**Approach:**

Approach is interdisciplinary and collaborative, combining computational modeling, human psychophysics and primate neurophysiology. Cortical activity in animal experiments will be traced using voltage-sensitive dyes and optical recording techniques.

**Progress:**

A central theme in interpreting results of studies of primate visual cortex is multiple processing pathways, each specialized for the extraction and analysis of specific attributes of the visual stimulus. But findings argue for more complex processing architecture that includes feedback and interaction among pathways. Experimental data are developed that support this view and identify brain areas that appear to facilitate cross talk.

**Report:**

DeYoe, E. A., & Van Essen, D. C., (1988). Concurrent processing streams in monkey visual cortex. Trends in Neuroscience, 11(5), 219-226.

# **PERCEPTUAL SCIENCE**

## **AUDITION**

7/20/03

**TITLE:** Recognition of Environmental Sound

**PRINCIPAL**

**INVESTIGATOR:** James A. Ballas  
George Mason University  
Department of Psychology  
(703) 323-2059

**R&T PROJECT CODE:** 4424205    **CONTRACT No:** N0001487K0167

**CURRENT END DATE:** 15 DEC 1989

**Objective:**

To establish the mediation processes that underlie the recognition of isolated sounds and the perception of multiple sounds, as single acoustic sequences, and to define those processes in terms of information-theoretic measures. The results of those studies will be important to other investigators who are interested in the development of a strong model of auditory classification for incorporation into a military systems for the recognition of non-speech acoustic transients.

**Approach:**

Experiments are conducted on the identification of the acoustic event that causes a particular sound to be generated and the measurement of the uncertainty of that identification. Techniques are developed to measure the encoding processes, and their operational sequence, for the recognition of environmental sounds.

**Progress:**

Experiments were completed that (a) assessed aspects of a listener's implicit knowledge; (b) described the effects of typicality and causal probability on identification; (c) demonstrated that information retrieval could not be cued with verbal labels; (d) assessed a set of sounds on a series of acoustic and perceptual attributes; and (e) determined the impact of context on the classification of environmental sounds.

**Report:**

Ballas, J. A., & Mullins, R. T. (1989). Effects of context on the classification of everyday sounds (Tech. Report).  
Fairfax, VA: George Mason University.

**TITLE:** Learning Environment for Neural Networks and Transient Acoustics

**PRINCIPAL**

**INVESTIGATOR:** Dan Greenwood  
Netrologic, Inc.  
(619) 587-0970

**R&T PROJECT CODE:** 400o042    **CONTRACT No:** Not available

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

To design an experimental research program that leads to the development of an automated decision-support aid or tutor, using several neural-network models, for the classification of transient acoustic signals.

**Approach:**

An intelligent tutoring system is designed in which the tutor judges the operator's knowledge state and suggests alternative strategies for the classification decision; and to achieve that goal, the transient acoustic information is encoded into semantic nets. Studies are directed toward the optimal elements for effective dialogue generation, a flexible architecture, most appropriate signal processing algorithms, and the network's ability to create new acoustic categories.

**Progress:**

This contract is new in FY89.

**TITLE:** Contextual Encoding of Acoustic Transients

**PRINCIPAL**

**INVESTIGATOR:** Thomas E. Hanna  
Naval Submarine Medical Research Laboratory  
Submarine Systems Department  
(203) 449-2561

**R&T PROJECT CODE:** 4424207     **CONTRACT No:** N0001489WR24008

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

To test theories of trace and context encoding in the classification of acoustic transients that arise from either active or passive sound sources. To assess the salient dimensions of synthesized transient sounds, their natural boundaries, the interdependence of spectral and temporal shape, and the identification of psychophysical dimensions, for classification performance.

**Approach:**

Transient sounds are synthesized with variations in the dimensions of spectral shape, temporal envelope, and spectral distribution, but at constant levels of loudness. Classification performance is determined with variable inter-signal intervals in order to test predictions from encoding theories. Predictions of classification performance are tested further with signals from active and passive sound sources taken from the ASW environment; and the robustness of the theories is extended to include broader ranges of signal types.

**Progress:**

Listeners' abilities to identify amplitude-modulation rate were measured and assessed the potential importance of various rates of modulation for aural classification of complex signals. Results indicated that rates above 100 Hz are resolved better than those below 100 Hz. Rates above 100 Hz convey important information for aural classification.

**Report:**

Hanna, T. E. (1989). Effects of stimulus range and stimulus spacing on modulation-rate perception (Tech. Report). Groton, CT: Naval Submarine Medical Research Laboratory.

**TITLE: Auditory Profile Analysis By Parallel Associative Networks**

**PRINCIPAL**

**INVESTIGATOR:** James H. Howard, Jr.  
Catholic University of America  
Department of Psychology  
(202) 635-5748

**R&T PROJECT CODE:** 4424213      **CONTRACT No:** N0001488K0261

**CURRENT END DATE:** 31 JAN 1991

**Objective:**

To extend the understanding of the profile analysis model of acoustic discrimination by developing a neural net model of the same acoustic phenomena. To test the neural net model for its discrimination of transient, multitonal signals in order to identify and quantitatively express the algorithms used for the processing of those signals, and to determine the algorithms for the classification of those sounds.

**Approach:**

Neural net models are developed which discriminate intensity changes in transient, multitonal signals which vary in (a) the number and spatial density of their components; (b) loudness level and its variability; and (c) frequency range. Learning characteristics of the neural network under different profile conditions are assessed. Structural parameters of the neural network are varied to determine the conditions that optimize the learning performance of the networks.

**Progress:**

Experiments have been completed that verify inferences from profile-analysis theory on (a) the improvement in discrimination performance as the frequency range of the background was increased; (b) the improvement in discrimination performance as signal duration was increased from 10 ms to 100 ms; and (c) that increases in the inter-stimulus interval have little effect on discrimination performance.

**Report:**

Howard, J. H., Jr., Harpster, J. L., & Miller, M. H. (1989). Profile analysis by parallel distributed networks. J. Acoust. Soc. Amer., 85 (Suppl. 1), 5-37.



**TITLE:** Central Factors in the Classification of Transient  
Acoustic Signals

**PRINCIPAL**

**INVESTIGATOR:** Robert A. Lutfi  
University of Wisconsin  
Waisman Center on Mental Retardation and Human  
Development  
(608) 262-7734

**R&T PROJECT CODE:** 4424226    **CONTRACT No:** N0001489J1281

**CURRENT END DATE:** 29 FEB 1992

**Objective:**

The objective is to determine the role of central factors such as learning, memory, and attention in the classification of complex acoustic signals with random variation similar to that occurring in naturally occurring signals.

**Approach:**

Psychophysical studies of normal hearing humans will be carried out to determine listeners' ability to integrate information across a wide range of stimulus dimensions, to overcome effects of stimulus uncertainty, and to weight information according to its reliability. Quantitative modeling studies will also be carried out to evaluate hypotheses generated by psychophysical experiments. The methods of signal detection theory will be applied in both experimental and modeling components of this project.

**Progress:**

This contract is new in FY89.

**TITLE:** Acoustical Cues for Sound Localization

**PRINCIPAL**

**INVESTIGATOR:** John C. Middlebrooks  
University of Florida  
Department of Neuroscience  
(904) 392-3177

**R&T PROJECT CODE:** 4424227    **CONTRACT No:** N0001489J1427

**CURRENT END DATE:** 31 DEC 1991

**Objective:**

The technical objectives of this study are to: (1) determine possible physical cues that may be used by the central nervous system to compute sound source location by making measurements of sound pressure in the human ear canals; and (2) measure in behavioral experiments the accuracy with which humans localize broad- and narrow-band sounds presented at unknown vertical and horizontal locations.

**Approach:**

Both acoustical and behavioral experiments will be carried out. In acoustical experiments, transient broad- and narrow-band sounds from a movable free field sound source will be presented to human participants while sound pressure is recorded from miniature microphones inserted into their ear canals. Spatial dependence of sound pressure levels and interaural level differences will be determined from amplitude spectra as a function of location. Interaural envelope delays will be computed from phase spectra. In behavioral experiments, participants are asked to turn their head toward the apparent location of the source, and head position is monitored with an electromagnetic device attached to the head. The pattern of localization errors is used to determine possible localization strategies.

**Progress:**

This contract is new in FY89.

**TITLE:** Principles of Perception in Bat Sonar

**PRINCIPAL**

**INVESTIGATOR:** James A. Simmons  
Brown University  
Department of Psychology  
(401) 863-1542

**R&T PROJECT CODE:** 4424202    **CONTRACT No:** N0001486K0401

**CURRENT END DATE:** 30 JUN 1992

**Objective:**

To determine the fine structure of the image of a sonar target as it is perceived by echo-locating bats and to understand the convergence of different representations of that image, i.e., psychophysical, computational, and physiological, that occur during the processes of fusion and formation.

**Approach:**

Target-ranging experiments employ a jittered-echo procedure to minimize the artifacts introduced by movements of the bat's head and to measure the shape of the acoustic image along an echo-delay or distance axis. Bats are trained in a two-alternative forced-choice procedure to discriminate between a simulated sonar target whose echoes alternate in delay and a simulated target whose echoes have a fixed delay for all transmissions. Echo delay is the acoustic cue used by the bat for the perception of the absolute distance to a target.

**Progress:**

The sensitivity of the bat for the detection of a sonar target was impaired by the presence of additional targets located at similar distances. At a range of 54 cm sensitivity to the target declined when the range separation to other targets was smaller than 8-9 cm. Echoes that fell within that range-band summed together to contribute collectively to detection. Acoustic glints or echoes within a band grouped together to be perceived as a single range-extended target of complex structure. Range bands defined a target by specifying within-target and between-target differences in range.

**Report:**

Simmons, J. A., Moss, C., & Ferragamo, M. (1983). Target images in the sonar of bats. (Tech. Rep. ONR-88-4). Providence, RI: Brown University, Department of Psychology.

**TITLE:** Augmentation of Neural Network Sonar Signal Processor  
by Bionic Processing Techniques

**PRINCIPAL**

**INVESTIGATOR:** Steven L. Speidel  
Naval Ocean Systems Center  
Code 632  
(619) 553-1557

**R&T PROJECT CODE:** 4424236    **CONTRACT No:** N0001489WX24234

**CURRENT END DATE:** 30 APR 1990

**Objective:**

To investigate, simulate, and demonstrate architectures for a neural network signal processor, a device which (1) forms a spatial map within a neural network through multiple interacting beams, (2) adaptively cancels interference, and (3) discriminates between targets and countermeasures.

**Approach:**

To design the neural network signal processor described above, construct a simulator test-bed system for performing real-world demonstrations and testing the design, and designing a integrated circuit implementation of the system.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** Interactive Neural Network System for Acoustic Signal Classification

**PRINCIPAL**

**INVESTIGATOR:** Nelson F. Steele  
Advanced Resource Development Corporation  
(301) 997-5600

**R&T PROJECT CODE:** 400o041    **CONTRACT No:** Not available

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

To design an experimental research program that specifies the most effective neural network for the classification of acoustic-transient signals, determines the utility of network output for joint classification of acoustic sources with human operators, and optimizes the effectiveness of interactive network-human allocations during signal processing.

**Approach:**

An interactive, multidimensional display system is designed to provide information on the current state of various types of network processors and their decision paths, and to accept requests from an operator for a particular decision path during the classification of active sonar returns from mines. Graphics in a menu environment are adapted to provide control of the network and to display multiple windows that represent the parallel processes.

**Progress:**

This contract is new in FY89.

**TITLE:** Cognitive Factors Affecting Sonar Classification

**PRINCIPAL**

**INVESTIGATOR:** Martin A. Tolcott  
Decision Science Consortium Incorporated  
(703) 620-0660

**R&T PROJECT CODE:** 4429012    **CONTRACT No:** N0001489C0029

**CURRENT END DATE:** 31 AUG 1990

**Objective:**

To design and conduct experimental studies that will elicit the role of cognitive factors in the sonar classification task, using skilled sonar operators as participants. To develop a normative model of sonar operator decision behavior in that task.

**Approach:**

To merge prior research data on signal classification and decision-making, collect experimental data on the sources of bias found in skilled sonar operators, specify the cognitive factors in the classification decision, and develop a normative model of classification behavior.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** Acoustic Classification with Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** Charles S. Weaver  
Maxim Technologies, Inc.  
(408) 748-1130

**R&T PROJECT CODE:** 400o043    **CONTRACT No:** Not available

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

To develop a time-delay neural network model for the recognition of a sequence of non-speech acoustical signals in noisy environments. Experiments are conducted with that model to determine effective modes of interaction with human operators engaged in classification decisions.

**Approach:**

A target-signal set is developed from acoustic transients. A time-delay neural network that segments sounds, which run together or overlap with background noise, is trained to classify those sounds. Experiments are conducted with a human operator interacting with the network to determine design principles for effective interaction with that network system.

**Progress:**

This contract is new in FY89.

**TITLE:** Development of a Three-Dimensional Auditory Display

**PRINCIPAL**

**INVESTIGATOR:** Elizabeth M. Wenzel  
National Aeronautics and Space Administration  
Ames Research Center  
(415) 694-6290

**R&T PROJECT CODE:** 4424235    **CONTRACT No:** N0001489WM24025

**CURRENT END DATE:** Not available

**Objective:**

The main objective of this work is to determine the validity of using the head-related transfer function (the transfer function resulting from filtering of the acoustic input by the outer ear) to synthesize cues for the 3-D spatial location of a virtual sound source.

**Approach:**

Behavioral experiments will test the ability of human participants to localize virtual sound sources presented over headphones. Virtual sounds will be synthesized by passing an acoustic signal (noise burst) through filters similar to those that would be imposed by the outer ears on a sound source originating from the simulated location.

**Progress:**

This action is new in FY89.

**Outside Funding:**

Funding for this project provided by ONT Code 222.



**PERCEPTUAL SCIENCE**

**HAPTICS AND SENSORY GUIDED  
MOTOR CONTROL**

100 A

**TITLE:** Panel on Classification of Complex, Non-Speech Sounds

**PRINCIPAL**

**INVESTIGATOR:** Milton A. Whitcomb  
NAS - National Research Council  
Committee on Hearing, Bioacoustics &  
Biomechanics  
(202) 334-3024

**R&T PROJECT CODE:** 4424204      **CONTRACT No:** N0001487C0272

**CURRENT END DATE:** 31 AUG 1988

**Objective:**

To review the current literature on complex sound processing by the auditory system in order to understand the status of the field, identify the salient areas of research, and assess current research activity on auditory classification. Visits are made to Navy laboratories in order to integrate findings into a better understanding for ASW operations relative to signal classification by machine and human operators.

**Approach:**

An expert panel is assembled in relevant areas of auditory system processing. The panel meets at least three times, conduct surveys of laboratories in the US and abroad working in the problem area, visits US Navy laboratories for information on current and anticipated research needs, and prepares an evaluative report on their findings.

**Progress:**

A literature review was prepared on the classification of acoustic transients and related areas. General guidelines were provided on areas that merit further study for an understanding of classification of complex sounds: the parsing of a sound into its probable sources; the integration of data on temporal sequences into a quantitative theory; the limits imposed by memory, attention, uncertainty, learning and internal noise on auditory processing; the development of methodologies for studying complex sounds; and the understanding of individual differences in performance of tasks that involve complex sounds.

**Report:**

CHABA. (1989). Classification of complex nonspeech sounds: Final Report. Washington, DC: National Academy Press.  
AD #A209 141.

**TITLE:** Committee on Hearing, Bioacoustics and Biomechanics

**PRINCIPAL**

**INVESTIGATOR:** Milton A. Whitcomb  
NAS - National Research Council  
Committee on Hearing, Bioacoustics &  
Biomechanics  
(202) 334-3024

**R&T PROJECT CODE:** 4426124      **CONTRACT No:** N0001487C0342

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

To provide information and assess status of current programs and to make recommendations on current and anticipated problems relevant to Navy and other federal agencies in the areas of hearing, bioacoustics, and biomechanics.

**Approach:**

Working groups address: hazardous exposure to impulsive, intermittent, and steady-state noise; effects of sound on hearing of divers during deep dives; exposure limits for vibration received by personnel in tracked vehicles and helicopters; effect of sonic booms produced by future commercial supersonic transport aircraft; auditory attentional deficit; evaluation of communication systems; aging in the central nervous system as it relates to perception of speech by older persons; and reversibility of presbycusis.

**Progress:**

A workshop of experts assessed digital speech-processing, VSLI technology, and other technologies which have been incorporated into noise-reduction techniques for the enhancement of noisy speech. These techniques have not been widely adopted because standardized tests fail to demonstrate gains in speech intelligibility, and generally lead to performance decrements. Participants at this workshop showed that those evaluation tests were limited in scope, yielded equivocal data, or employed non-discriminatory measures.

**Report:**

CHABA. (1989). Removal of noise from noise-degraded speech signals. Washington, DC: National Academy Press.

**Outside Funding:**

Partial funding provided by NSF, NMRDC, AMRDC, NIA-NIH, NSA, USAF-AMD, and NASA.

# HAPTICS AND SENSORY GUIDED MOTOR CONTROL

103/104

**TITLE:** The Psychophysics of Motor Learning

**PRINCIPAL**

**INVESTIGATOR:** Christopher G. Atkeson  
Massachusetts Institute of Technology  
Department of Brain & Cognitive Sciences  
(617) 253-0788

**R&T PROJECT CODE:** 4424217    **CONTRACT No:** N0001488K0321

**CURRENT END DATE:** 30 JUN 1990

**Objective:**

The objective is to develop the empirical base for biologically plausible computational models of motor coordination and control for potential application in teleoperator and robotic systems.

**Approach:**

Psychophysical, biomechanical, and kinematic data will be obtained from human participants to provide the empirical basis for computational models of the parameters explicitly controlled by the nervous system during the learning and performance of skilled motor activity.

**Progress:**

Single joint experiments have been initiated to test the hypothesis that the human movement control system is specialized to produce straight line movements with symmetric bell shaped tangential velocity profiles. The results generally support the hypothesis, revealing that non-straight line trajectories are not as accurately produced or perceived as are straight line trajectories. These results will be compared with those of multi-joint experiments to reveal the stage of learning at which the invariant features of movement appear and whether the learning strategies are similar for single- and multi-joint movement.

**TITLE:** Neural Feedback and Musculo-Skeletal Mechanics

**PRINCIPAL**

**INVESTIGATOR:** Emilio Bizzi  
Massachusetts Institute of Technology  
Department of Brain and Cognitive Sciences  
(617) 253-5769

**R&T PROJECT CODE:** 4424216    **CONTRACT No:** N0001488K0372

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

Objective is to produce biologically plausible computational models of human arm and hand sensorimotor control for potential implementation in teleoperator and robotic devices.

**Approach:**

The approach is a combination of neurophysiological experiments, behavioral investigations, mathematical modeling and theoretical studies of the computational tasks performed by the brain in the control of motor behavior. Model-based experiments are conducted to quantitatively model movement planning, execution and functional manipulation.

**Progress:**

Unconstrained aiming movements of a limb were represented and generated by a neural network architecture. The network produced a time trajectory of a limb from a starting posture toward a target specified by a sensory stimulus. The network carried out a sensory-motor transformation. The network was constrained to produce trajectories with a bell-shaped velocity profile, a characteristic of movements in biological systems. The network was coupled to a mechanical model of a limb in which muscles were represented as springs.

**Report:**

Massone, L. & Bizzi, E. (1989). A neural network model for limb trajectory formation (Tech. Report). Cambridge, MA: MIT, Department of Brain and Cognitive Sciences.

**TITLE:** The Cortical Substrate of Haptic Representation

**PRINCIPAL**

**INVESTIGATOR:** Joaquin M. Fuster  
University of California, Los Angeles  
School of Medicine  
(213) 825-0247

**R&T PROJECT CODE:** 4425800    **CONTRACT No:** N0001489J1805

**CURRENT END DATE:** 28 FEB 1992

**Objective:**

The primary objective of this work is to understand the functional organization of areas of primate cerebral cortex that represent tactile and visual information, with particular emphasis on the interaction of tactile and visual stimuli in the cortical representation of external objects.

**Approach:**

The role of posterior parietal cortex in the representation of physical objects will be explored by examining the effects of reversible cryogenic lesions of this cortical area in monkeys on short-term memory of haptically or visually perceived objects. Functional organization of parietal neurons during short term memory tasks will be explored with microelectrode recording. Single unit recordings will also be analyzed to investigate neuronal mechanisms underlying attention to an object.

**Progress:**

Data on the development of haptic learning in primates has been gathered during training of the monkeys. These data indicate that performance on a short term memory task is more efficient when visual presentation of an object is followed by tactile recognition, than two other performance schemes: haptic-haptic and haptic-visual. Single unit studies of parietal neurons in areas 2 and 5 have provided evidence that these neurons are involved in sensorimotor integration.

**Report:**

Quintana, J., Yajeya, J., & Fuster, J. M. (1988). Prefrontal representation of stimulus attributes during delay tasks. Brain Research, 474, 211-230.

**TITLE:** Mechanisms of Eye-Hand Coordination

**PRINCIPAL**

**INVESTIGATOR:** Apostolos P. Georgopoulos  
The Johns Hopkins University  
Department of Neuroscience  
(301) 955-8334

**R&T PROJECT CODE:** 4424224    **CONTRACT No:** N0001488K0751

**CURRENT END DATE:** 30 SEP 1991

**Objective:**

To elucidate the mechanisms of eye-hand coordination at the psychophysical (behavioral), neurophysiological, and computational levels.

**Approach:**

To define the behavioral capabilities of human and monkey subjects in eye-hand coordination, characterize the patterns of activity of single cells in the monkey motor cortex during eye-hand coordination tasks, and to model the involvement of neuronal populations in the motor cortex during the performance of such tasks.

**Progress:**

Training of monkeys on the force-tracking task is in progress, and psychophysical studies of human performance in the force-tracking task have begun. Preliminary work on electrophysiological experiments has also begun.



**TITLE:** Matrix SM 1281 Color Graphics System and Subsystem for  
Information Processing in Perceptual Motor Systems

**PRINCIPAL**

**INVESTIGATOR:** Apostolos P. Georgopoulos  
The Johns Hopkins University  
Department of Neuroscience  
(301) 955-8334

**R&T PROJECT CODE:** dipn231    **CONTRACT No:** N0001489J1246

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

The DOD Defense-University Research Instrumentation Program was designed to improve the capabilities of U.S. universities to conduct DOD-relevant research by supporting the purchase of major equipment critical to the conduct of that research. This effort helps purchase equipment that supports research on neurophysiological studies of information processing in perceptual-motor systems.

**Approach:**

The equipment purchased through this grant enables the PI to generate virtual 3-D object images and to record neurophysiological responses as subjects (macaque monkeys) make force control movements appropriate to reach toward and touch these objects.

**Progress:**

This contract is new in FY89.

**TITLE:** Workshop on Computational Approaches To Neuroscience

**PRINCIPAL**

**INVESTIGATOR:** Susan Hockfield  
Cold Springs Harbor Laboratory  
Neurobiology Program  
(203) 785-5944

**R&T PROJECT CODE:** 4424220    **CONTRACT No:** N0001488J1165

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

Objectives are to: (1) conduct interdisciplinary workshops on computational approaches to neuroscience; (2) identify and test advanced computational models of ocular motor control, vision and sensory guided motor control; and (3) promote interdisciplinary collaboration and training among scientists working in the life sciences and the physical sciences on research projects in the rapidly growing field of computational neuroscience.

**Approach:**

Senior scientists, graduate students and post doctoral fellows in biology, psychology, computer science, engineering and physics will participate in workshops during the summers over the next three years. The workshops will consist of tutorials and hands-on laboratory sessions during which advanced computational models will be described, implemented and tested in computer simulations. Model results will be compared with actual data sets and the merits of the models will be evaluated.

**Progress:**

A workshop on computational approaches to ocular motor control was conducted 5 - 9 July 1988.

**Report:**

Optican, L. M. (1988). Refining ocular motor models through simulation: Workshop on computational neuroscience (Final Report). Cold Spring Harbor, NY: Cold Spring Harbor Laboratory.

**TITLE:** Models for Hand Movement and Teleoperator Control

**PRINCIPAL**

**INVESTIGATOR:** John M. Hollerbach  
Massachusetts Institute of Technology  
Artificial Intelligence Laboratory  
(617) 253-5798

**R&T PROJECT CODE:** 4424215    **CONTRACT No:** N0001488K0338

**CURRENT END DATE:** 30 APR 1990

**Objective:**

Objective is to produce biologically plausible computational models of human hand grasping and manipulation for potential implementation in teleoperator and robotic devices.

**Approach:**

The approach is a synthesis of mechanical engineering, biomechanics and biological motor control guided by a competence model of hierarchical movement-planning and control structures. Computer simulation and model-based experiments are conducted to quantitatively investigate human hand and teleoperator trajectory planning, grasping, fine motion control and regrasping at the object, joint and activator levels.

**Progress:**

The Linear Grasp Tester is fully on line; computer control and protocols for testing of human perception of length and stiffness have been implemented. Preliminary experiments have been conducted on the perception of stiffness, and results have been published on the perception of length. A force-reflecting master glove for the Utah/MIT hand is being constructed.

**TITLE:** Modular Conceptions of Timing and Sequencing in Motor Behavior

**PRINCIPAL**

**INVESTIGATOR:** Steven W. Keele  
University of Oregon  
Department of Psychology  
(503) 686-4931

**R&T PROJECT CODE:** 4426802    **CONTRACT No:** N0001487K0279

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

The objective is to carry out behavioral experimentation with normals and brain-damaged patients to establish the separability of the modular components of coordinated action and to demonstrate the central neural basis of each.

**Approach:**

Both normals and brain-damaged patients are tested. Data taken from normals will be used to assess the independence of the timing, force, sequencing, and configuring components of coordinated motor function. Data from brain-damaged patients are used to establish the anatomical basis of each component function.

**Progress:**

An extensive series of experiments have now been completed with both normal and brain-damaged patients to examine the fundamental components of motor control (timing, force, sequencing) which are represented in a modular fashion in the brain. The findings have significant implications for the understanding of motor function and the computational mechanisms by which it is controlled.

**Report:**

Keele, S. W., Cohen, A., & Ivry, R. I. (in press). Motor programs: Concepts and issues. In M. Jeannerod (Ed.), Attention and performance XIII. Hillsdale, NJ: Erlbaum, 1989.

**TITLE:** Complex Sensorimotor Behavior: Biological Control Structures and Constraints

**PRINCIPAL**

**INVESTIGATOR:** J.A.S. Kelso  
Florida Atlantic University  
Center for Complex Systems  
(305) 538-2230

**R&T PROJECT CODE:** 4424223    **CONTRACT No:** N0001488J1191

**CURRENT END DATE:** 31 JUL 1991

**Objective:**

To develop the theoretical and empirical base for a unified control theory of motor function, applicable across both rhythmic and discrete movement domains.

**Approach:**

To conduct psychophysical and motor performance experiments with human participants and develop non-linear dynamical analyses the results of these experiments, leading to a formal theoretical formulation of the dynamics of sensory-guided reaching and grasping behavior.

**Progress:**

A dynamic pattern theory of voluntary discrete movement behavior was developed. Key elements of this theory are that destabilizing signals contain no precoded information about the specifics of the trajectories, and that it is primarily the dynamics that define the trajectory shape and timing.

**Report:**

Kelso, J. A. S., & Schoener, G. (1988). Dynamic patterns of sensorimotor behavior: Biological control structures and constraints. Neural Networks, 1(1), 343.

**TITLE:** Object Exploration and Recognition by Humans and Machines

**PRINCIPAL**

**INVESTIGATOR:** Roberta L. Klatzky  
University of California, Santa Barbara  
Department of Psychology  
(805) 961-3948

**R&T PROJECT CODE:** 4424200    **CONTRACT No:** N0001486K0232

**CURRENT END DATE:** 30 APR 1989

**Objective:**

The objectives are: (1) to develop functional relationships between haptic exploration procedures and object properties; (2) to incorporate the functional relationships into a computational model of haptic apprehension and object recognition; (3) to reconcile differences between psychological and robotic models of object recognition by touch and manipulation.

**Approach:**

The approach is an integrated, interdisciplinary program that includes modeling, experimentation, and computer simulation by psychologists (Klatzky and Lederman) and computer scientists (Bajcsy).

**Progress:**

A study on categorization of real objects has been completed. Data from this study indicate that there are differences in the nature of haptic categorization at different levels of abstraction (Klatzky and Lederman lab). A prototype of the dextrous three-fingered hand is being tested for motor capabilities (Bajcsy lab).

**Report:**

Lederman, S. J., Browse, R. A., & Klatzky, R. L. (1988). Haptic processing of spatially distributed information. Perception & Psychophysics, 44, 222-232.

Klatzky, R., Lederman, S. J., & Reed, C. (1989). Haptic integration of object properties: Texture, hardness, and planar contour. J. of Experimental Psychology: Human Perception and Performance.

Bajcsy, R. (1988). Active perception. Proceedings of the IEEE, Vol. 76 (8).

**TITLE:** Peripheral Neural Mechanisms of Haptic Touch:  
Softness and Shape

**PRINCIPAL**

**INVESTIGATOR:** Robert H. LaMotte  
Yale University  
School of Medicine  
(203) 785-2802

**R&T PROJECT CODE:** 4424218    **CONTRACT No:** N0001488K0604

**CURRENT END DATE:** 30 JUL 1990

**Objective:**

The objective is to develop the psychophysical and neurobiological basis for biologically plausible computational models of human hand grasping and object manipulation for potential implementation in teleoperator and robotic devices.

**Approach:**

Psychophysical data from humans and monkeys and physiological data from monkeys are gathered to determine the capabilities of these systems to discriminate softness and shape, and to determine the neural code underlying these discrimination capabilities.

**Progress:**

Ringblock of the fingers was shown to grossly impair softness discrimination in humans. Experiments have also shown that cold blocking the receptors in the skin of the fingerpads causes humans to perceive objects as less compliant than they are perceived to be when tactile sensation is normal.

# HUMAN FACTORS TECHNOLOGY

117/118



**TITLE:** Personalized and Prescribed Information Handling

**PRINCIPAL**

**INVESTIGATOR:** Luiz Cabral  
Naval Underwater Systems Center  
Combat Control Systems Department  
(401) 841-2648

**R&T PROJECT CODE:** 4429013    **CONTRACT No:** N0001489AF0001

**CURRENT END DATE:** 30 SEP 1990

**Objective:**

To test theories of information handling under conditions of variable uncertainty of the information and at different levels of risk to the decision-maker. To assess the effectiveness of personalized and prescriptive display systems for decision support by experienced Naval officers within an interactive submarine engagement simulation.

**Approach:**

To incorporate software for the specification of uncertainty and risk, install display and control functions for prescriptive and personalized information-handling systems, and develop submarine-attack planning scenarios into the interactive submarine engagement simulation facility. Conduct pilot studies on the effectiveness of those decision support technologies.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** On Line Aiding for Human-Computer Interfaces

**PRINCIPAL**

**INVESTIGATOR:** Jay Elkerton  
University of Michigan  
Dept. of Industrial and Operations Engineering  
(313) 763-0464

**R&T PROJECT CODE:** 4429008    **CONTRACT No:** N0001487K0740

**CURRENT END DATE:** 14 AUG 1990

**Objective:**

To refine graphical-aiding dialogues and to validate their performance on the computer-based tasks of interactive file search, interaction with window-based interfaces, and the user interface to computer-aided design. To develop usability indices for the identification and measurement of the critical performance components of graphical dialogues for on-line help and instruction.

**Approach:**

Extend the Model Human Processor of Newell et al. to include the quantitative analysis of the components that are elicited during on-line graphic aiding with computer-based systems. Conduct experimental studies to validate the model and to derive usability indices of task design.

**Progress:**

Animated demonstrations on a Hypercard system were compared with written instructions for the task of learning interface procedures. Demonstrations proved to be faster and led to more accurate initial learning but when instructions were removed, the users were apt to take as much or even more time for task completion than users of written instructions alone. The advantage of animated demonstration was limited to interfaces that are highly graphic with few hidden responses to user input.

**Report:**

Palmiter, S., Elkerton, J., & Baggett, P. (1989). Animated demonstrations versus written instructions for learning procedural tasks (Tech. Rep. C4E-ONR-2). Ann Arbor, MI: University of Michigan, Center for Ergonomics. AD #A189 239.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** Classification of Single Epoch Evoked Potentials (EP)  
and Evoked Magnetic Fields (EF) Using Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** Micha Hohenberger  
Temple University  
Department of Electrical Engineering  
(215) 787-8520

**R&T PROJECT CODE:** 4424238    **CONTRACT No:** N0001489J1978

**CURRENT END DATE:** 30 APR 1990

**Objective:**

The objective is to comparatively evaluate several alternative neural networks with respect to their utility in classifying single epoch evoked potentials and evoked magnetic fields with respect to their relation to psychophysical performance.

**Approach:**

Several alternative neural networks, including bidirectional associated memory, multilayered back propagation, and counter propagation, will be compared with respect to their capability to classify single epoch (or epoch averaged) evoked potentials and evoked magnetic fields recorded during a prior psychophysical experiment at NPRDC.

**Progress:**

This contract is new in FY89.

**TITLE:** Understanding and Enhancing Graphics Displays for Maintenance

**PRINCIPAL**

**INVESTIGATOR:** William B. Johnson  
Search Technology, Inc.  
(404) 441-1457

**R&T PROJECT CODE:** 4428018    **CONTRACT No:** N0001489C0047

**CURRENT END DATE:** 30 NOV 1991

**Objective:**

To provide research results that will provide guidance on how graphical information should be presented to maintainers of complex systems and to test theories on the design of graphic information-presentation for diagnostic problem-solving.

**Approach:**

Analyze candidate Navy maintenance tasks to define the problem space and develop a taxonomy of cognitive activities for those tasks. Develop display concepts for large-scale graphic representations and conduct pilot studies to assess those graphic displays in terms of their levels of aggregation and abstraction. Select and design graphic displays for formal experimentation at the Naval Training Systems Center laboratory.

**Progress:**

An operational squadron of SH3 helicopters in Jacksonville, FL was selected as the maintenance environment in which to evaluate the results of the research program; this site affords a setting in which there is mix of simulators (cockpit procedures and weapon systems trainers) and operational equipment. Software packages for the development and design of maintenance graphics, and available on microcomputers, were identified and reviewed.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** Decision Making in Naval Command Teams

**PRINCIPAL**

**INVESTIGATOR:** David L. Kleinman  
University of Connecticut  
Dept. of Electrical & Systems Engineering  
(203) 486-3066

**R&T PROJECT CODE:** 4429010     **CONTRACT No:** N0001488K0545

**CURRENT END DATE:** 31 AUG 1991

**Objective:**

To investigate decision strategies, information structures, communication protocols, and process feedback as mechanisms to improve coordination in resource allocation and management tasks in command and control systems.

**Approach:**

A normative-descriptive modeling framework is designed and developed that is based on a computer-based, human-in-the-loop paradigm. Experiments are conducted to investigate the effectiveness of decision strategies under time stress, degraded communications, and resource constraints.

**Progress:**

A dynamic decision-making paradigm was developed for performance assessment of small teams of decision makers operating in a distributed environment. The task environment is an abstraction of a naval battle group in which a team of geographically distributed commanders make coordinated decision based on uncertain, ambiguous, and decentralized information. A set of team-oriented performance measures was defined.

**Report:**

Kleinman, D. L., & Serfaty, D. (1989). Team performance assessment in distributed decision making. In Proceedings of Symposium on Interactive Networking for Simulation. Orlando, FL: Naval Training Systems Center.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** Strategies for Understanding and Maintenance of  
Large-Scale Software Systems

**PRINCIPAL**

**INVESTIGATOR:** Thomas G. Moher  
University of Illinois at Chicago  
Dept. of Electrical Engineering & Computer Sci.  
(312) 996-3422

**R&T PROJECT CODE:** 4429006    **CONTRACT No:** N0001487K0413

**CURRENT END DATE:** 14 NOV 1988

**Objective:**

To ascertain problem-solving strategies associated with the search of large information systems in order to test theories of problem identification based on discrete and distributed search strategies, and to develop metrics that characterize search strategies and quantify their accuracy and efficiency.

**Approach:**

Conduct experiments with experienced programmers engaged in the task of modifying software code of at least 20K lines in size. Electronic, audio, and video recordings are collected of user performance during this task and the data are analyzed to define and measure the search and problem-solving strategies that are adopted by the users.

**Progress:**

Experimental studies demonstrated that top-down, bottom-up, and heuristic strategies were employed in the comprehension of large-scale software code; no particular strategy led to exceptionally better performance. Specific sub-plans are invoked during search without reference to higher-level data structures; several techniques were employed by programmers to operationalize their sub-plans. A model was developed of program modification which described coordinated search through three mutually-constraining spheres of knowledge: debugging plans, the software program, and the domain problem.

**Report:**

Lange, B. M., & Moher, T. G. (1988). Some strategies of reuse in an object-oriented programming environment. In K. Bice, & C. Lewis (Eds.), CHI '89 Conference Proceedings: Human factors in computing systems (pp. 69-73). Reading, MA: Addison-Wesley.

**Outside Funding:**

Funding provided by ONT Code 222.

**PERCEPTUAL SCIENCE**

**HUMAN FACTORS TECHNOLOGY**

124a.

**TITLE:** Modeling Human-Computer Interaction

**PRINCIPAL**

**INVESTIGATOR:** Allen Newell  
Carnegie-Mellon University  
Department of Computer Science  
(412) 578-2806

**R&T PROJECT CODE:** 4429005     **CONTRACT No:** N0001487K0432

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

To extend a predictive model of human performance (Model Human Processor) for interaction with computing systems by decomposing composite operators (perceptual, motor, and cognitive), estimating their boundary conditions, introducing weighting factors to account for individual differences, and assessing the stimulus-response compatibility of various user tasks.

**Approach:**

Response-time data that are available in the literature are analyzed for their operators (perceptual, motor, cognitive, etc.), and the stability of their measures, in order to develop predictive models of human response times for various human-computer interaction tasks. The SOAR general cognition theory is utilized to provide a formal language that allows simulations to be run on those human performance data to evaluate, quantitatively, learning mechanisms, perceptual processes, and problem-solving procedures.

**Progress:**

A model of immediate-response behavior was developed and its parameters estimated to predict performance time on similar tasks within an absolute error of 19% for the sequential task of generating the abbreviation of a command given the full name of that command. Another model of behavior with longer durations and parallel operation, i.e., transcription typing, was developed and its parameters estimated. This model predicted with about 20% accuracy the data reported on transcription typing performance. Four operators were required for these models: perceptual, cognitive, motor, and retrieval.

**Report:**

John, B. E., & Newell, A. (1989). Cumulating the science of HCI: From S-R compatibility to transcription typing. In K. Bice, & C. Lewis (Eds.), CHI '89 Conference Proceedings: Human factors in computing systems (pp. 109-114). Reading, MA: Addison-Wesley.

**Outside Funding:**

Funding provided by ONT Code 222.



**TITLE:** Goal and Plan Knowledge in Software Comprehension

**PRINCIPAL**

**INVESTIGATOR:** Scott P. Robertson  
Rutgers University  
Department of Psychology  
(201) 932-2553

**R&T PROJECT CODE:** 4424203      **CONTRACT No:** N0001486K0876

**CURRENT END DATE:** 30 SEP 1990

**Objective:**

To develop a cognitive model of task comprehension, using the task of revising software code, that emphasizes the role of language constructs and syntax, the organization of planning knowledge, and the understanding of goal knowledge. To predict the effects of plan structures and the role of sources of the participant's knowledge on the understanding of a complex task.

**Approach:**

Experiments are conducted to determine how task comprehension is facilitated by prior provisions of schematic knowledge structures such as goal-based and function-based summaries of the task. A deeper understanding of a complex task requires knowledge of specific lower-level goals and studies are conducted to evaluate effective methods for the presentation of that information to the participants. These experiments will reveal the interaction between abstract, planning, and concrete knowledge in the comprehension of a task.

**Progress:**

In a series of studies, the use of plan-based abstractions to comprehend a task was demonstrated to serve as organizing cognitive structures. Participants employed both general plan-information and task-specific constructs but the primary criterion was plan-based; in the comprehension of software code, the plans were common across different programming languages.

**Report:**

Koenemann, J., Robertson, S., & Davis, E. (1989). Program comprehension as design reconstruction (Tech. Report). New Brunswick, NJ: Rutgers University.

**Outside Funding:**

Funding provided by ONT Code 222.

**TITLE:** NRC-Committee on Human Factors

**PRINCIPAL**

**INVESTIGATOR:** Harold P. Van Cott  
NAS - National Research Council  
Committee on Human Factors  
(202) 334-3027

**R&T PROJECT CODE:** 4424167    **CONTRACT No:** N0001485G0093

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

To conduct analytic studies, workshops, symposia, and gather the requisite data to evaluate current theories, topics, and problems in human performance.

**Approach:**

To define and address these current problems in human performance of relevance to sponsor's programs, assemble experts in those areas, and analyze the available data through the medium of jointly-authored reports, workshops, or symposia on (a) human error in a technological society; (b) augmentation of human intellectual functioning by computer; and (c) the relationships between individual and organizational performance-effectiveness.

**Progress:**

Studies were completed on (a) human factors in automated and robotic space systems; (b) mental models in human-computer interaction; (c) ergonomic models; and (d) human reliability, risk assessment, and automatic aiding. Reports are in preparation on human performance models, distributed decision-making, multi-colored displays, knowledge elicitation and representation for expert systems, effects of aging on human performance, and visual and cognitive models of pilot performance.

**Report:**

Elkind, J. I., Card, S. K., Hochberg, J., & Huey, B. M. (Eds.), (1989). Human performance models for computer-aided engineering. Washington, DC: National Academy Press.

**TITLE:** Event Related Potential Correlates of Memory  
Performance

**PRINCIPAL**

**INVESTIGATOR:** Diane Williams  
Navy Personnel Research and Development Center  
(619) 553-7925

**R&T PROJECT CODE:** 4424230    **CONTRACT No:** N0001489AB68221

**CURRENT END DATE:** 30 APR 1990

**Objective:**

This research investigates the suffix and modality effects in short term memory as well as implicit and explicit memory. Behavioral measures will be obtained to confirm these effects. Evoked brain activity will be recorded and analyzed to obtain real-time assessment of these phenomena. The data acquired could lead to improved predictive capabilities of success in school and job performance.

**Approach:**

Collect measures of brain electrical activity while subjects are engaging in memory tasks. Analyze averaged evoked potentials based upon the subject's ability to recall the stimulus.

**Progress:**

This contract is new in FY89.

**TITLE: Information Processing Models for Adaptive Computer Interfaces**

**PRINCIPAL**

**INVESTIGATOR:** Wayne W. Zachary  
CHI Systems, Inc.  
(215) 275-2355

**R&T PROJECT CODE:** 4429007    **CONTRACT No:** N0001487C0814

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

To formulate computational models underlying information processing of the tactical coordinator in airborne ASW mission management. To develop an adaptive computer interface for mission management which adjusts its computations to the attention flow of the operator and the evolution of mission events.

**Approach:**

Theoretical formalisms for planning and problem solving such as Newell's Model Human Processor and Hayes-Roth's Blackboard Model are extended and merged to develop computational models of information processing and decision-making. The models are used in conjunction with AI techniques for plan recognition in order to provide a basis for an adaptive interface for mission management. Experiments are conducted to test the models and the adaptive interface.

**Progress:**

A laboratory facility was designed to conduct research on the simulated air ASW mission and a work station to represent it, experimental tools were designed, tools were developed for data collection, and other tools were designed to translate data into timelines and other forms to support the building of cognitive models of the human operator.

**Report:**

Zachary, W., & Zubritzky, M. C. (1988). An experimental environment and laboratory for studying human information processing in Naval air ASW (Tech. Rep. 881020.8704). Blue Bell, PA: CHI Systems, Inc. AD #A204774.

**Outside Funding:**

Funding provided by ONT Code 222.

**BIOLOGICAL INTELLIGENCE**

**COMPUTATION IN LARGE NEURAL  
NETWORKS**

*131/132*

**TITLE:** Neural Networks for Adaptive Control

**PRINCIPAL**

**INVESTIGATOR:** Andrew Barto  
University of Massachusetts, Amherst  
Computer and Information Science  
(413) 545-1309

**R&T PROJECT CODE:** a44e006    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this research is to (a) compare neural network and conventional approaches to robust and adaptive control, (b) develop novel network architectures and learning methods specialized for control, and (c) test network based control methods on control tasks for which expert controllers do not currently exist.

**Approach:**

The research will consist of the following projects: (a) Neural networks will be investigated for controlling systems with hard non-linearities in the form of transitions between modes. Reinforcement learning methods will be used to select between mode controllers, including the use of cascaded backpropagation networks. (b) Cascaded backpropagation nets will be used to identify a multilinear map derived from a robust control problem. Cascaded backpropagation nets effectively permit the output of one net to modulate the weights of another net thereby mimicking the kernels of multilinear maps. (c) Adaptive networks will be used to model a feedback control process with pulse-width modulation inputs, in order to identify the inverse of this nonlinear process. (d) Compare nets with reinforcement learning with temporal-difference methods with conventional solutions on a time-optimal control problem. (e) Use neural networks to model and control dynamics of distributed processes: control of fractal of Ising model, and dynamics of polymer blending. (f) Use neural nets to model turbulence, mixing dynamics, and noise control.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project are provided by DARPA and NSF.

**TITLE:** Changes in Neuronal Network Properties Induced by Learning and Synaptic Plasticity: A Nonlinear Systems Approach

**PRINCIPAL**

**INVESTIGATOR:** Theodore W. Berger  
University of Pittsburgh  
Department of Behavioral Neuroscience  
(412) 624-4562

**R&T PROJECT CODE:** 4426817    **CONTRACT No:** N0001487K0472

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

Investigate potential changes in system properties of the hippocampus induced by discrimination reversal conditioning of the nictitating membrane (NM) response. Classical conditioning of the rabbit NM response will be used in these experiments because it is one of the most widely used behavioral paradigms for the studying of the neuronal substrates of associative learning in mammals. The second objective is to produce a computational structure which simulates the hippocampal system functions of learning and memory.

**Approach:**

The approach of this proposal is an in-depth study of the functional network properties of the hippocampal formation, a brain structure long known to be critical for learning and memory functions. The first phase utilizes nonlinear systems analytic techniques to characterize the transformational properties of networks of neurons comprising the hippocampus, and in defining the contributions to network properties of individual subpopulations of hippocampal neurons. The second phase, involves the formulation of a state-space model of hippocampal system function based on results from the nonlinear systems characteristics of the hippocampus.

**Progress:**

PI is using nonlinear systems theory and analytical procedures to characterize transformational properties of hippocampal subsystems at levels of neuronal populations, single cells, and subcellular. The resulting characterizations are being used in a computer simulation to reconstruct and investigate biological neural network properties.

**Report:**

Sclabassi, R. J., Krieger, D. N., Berger, T. W. (1988). A systems theoretic approach to the study of CNS function. Ann. Biomed. Engineering, 16:17-34.

Berger, T. W., Harty, T. P., Barrionuevo, G., Sclabassi, R. J. (1989). Modeling of neuronal networks through experimental decomposition. In V. Z. Marmarelis (Ed.), Advanced methods of physiological system modeling. NY, Plenum Pub., in press.

**TITLE:** Computational Theory and the Olfactory System

**PRINCIPAL**

**INVESTIGATOR:** James M. Bower  
California Institute of Technology  
Department of Biology  
(818) 356-6817

**R&T PROJECT CODE:** 4426136    **CONTRACT No:** N0001488K0513

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

To forge a link between components of abstract neural network processing and the detailed anatomy and physiology of an actual neural system. This proposal links theoretical neural network models studied by Hopfield to actual structural components of the olfactory system studied by Bower. This linkage will be performed using the neural network simulation facility that the PI has been constructing at Caltech.

**Approach:**

This project will develop physiological techniques for recording neuronal activity in behaving animals (albino rats). This approach will involve recording simultaneously from numerous neurons in the mitral cell layer of the olfactory bulb while the animal is performing olfactory discrimination tasks. The primary objective will be to determine the nature of stimulus encoding in the olfactory system and the role of this encoding in learning and memory.

**Progress:**

Investigation of olfactory cortex employing a combination of realistic computer simulations, in vitro electrophysiology, and in vivo multiunit recording continue. The simulations have expanded to parallel computers which enable a simulation of thousands of biophysically realistic neurons. Cortical distribution of receptor types has been included, and a simulated olfactory bulb linked to the olfactory cortex. The Genesis simulation system has been widely distributed as a tool and is the basis for the summer course in Computational Neuroscience at MBL.

**Report:**

Bower, J. M. (1989). Reverse engineering the nervous system: An anatomical, physiological, and computer based approach. In S. Zornetzer, J. Davis, & C. Lau (Eds.), An introduction to neural and electronic networks. Academic Press.

Wilson, M. & Bower, J. M. (1989). The simulation of large-scale neuronal networks. In C. Koch & I. Segev (Eds.), Methods in neuronal modelling: From synapses to networks. MIT Press.

Haberly, L. B. & Bower, J. M. (1989). Olfactory cortex: Model circuit for study of associative memory? Trends in Neuroscience, 12, 258-264.



**TITLE:** Dynamic Biophysical Theory for the Role of Hippocampal Neural Networks in the Declarative Memory System

**PRINCIPAL**

**INVESTIGATOR:** Thomas H. Brown  
Yale University  
Department of Psychology  
(818) 357-9711

**R&T PROJECT CODE:** 4426200     **CONTRACT No:** N0001488K0313

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

To understand how the circuitry of the hippocampus carries out its adaptive functions. The network level model will capture the time-dependent aspects of neural computation, i.e., the neurodynamics. It will show how the neurodynamics emerge from the cellular neurophysiology and biophysics. The model will be tightly linked to experimental knowledge of cellular neurophysiology and biophysics.

**Approach:**

Neurons will be examined with brain slice techniques to form realistic representations of the principle neuronal types (e.g. CA1 and CA3 pyramidal neurons, granule and basket cells). Voltage signalling in the dendritic arborization will be explored. I/O (synaptic input to spike output) will be quantified to understand adaptive network neurodynamics.

**Progress:**

Network simulations were used to test a covariance Hebbian rule, and to evaluate the ability of the sparse connectivity of mossy fiber input to CA3 to orthogonalize an autoassociative operation carried out by the hippocampus. The PI made the first direct demonstration of Hebbian plasticity. Biophysical modelling of dendritic spines incorporating NMDA receptors predicted that the long time course of NMDA mediated currents should produce a 100 ms trace period following synaptic input, during which postsynaptic activity in CA1 neurons may result in LTP induction. The PI is exploring the hypothesis that single biologically realistic neurons are equivalent to higher order artificial neural networks.

**Report:**

Brown, T. H., Chapman, P. F., Kairiss, E. W., & Keenan, C. L. (1988). Long-term synaptic potentiation. Science 242, 724-728.

Brown, T. H., Kairiss, E. W., & Keenan, C. L. (1990). Hebbian synapses: Biophysical mechanisms and algorithms. Annual Review of Neuroscience.

Brown, T. H., Ganong, A. H., Kairiss, E. W., Keenan, C. L., & Kelso, S. R. (1989). Long-term potentiation in two synaptic systems of the hippocampal brain slice. In J. H. Byrne & W. O. Berry (Eds.), Neural models of plasticity. Academic Press.

**TITLE:** Neural Networks: Theory and Modeling Analysis of the  
Comparative Value of Artificial Neural Network Systems

**PRINCIPAL**

**INVESTIGATOR:** Dr. Monte S. Chawla  
System Planning Corporation  
(703) 841-2800

**R&T PROJECT CODE:** a44f001    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this study is to track and document the comparative performance measurements, the match of neural net type to task, and novel algorithms produced in the course of the DARPA neural network program.

**Approach:**

SPC will receive the quarterly reports sent by approximately 50 DARPA Neural Net contractors, record the reports in a database executable on a desktop computer, abstract the reports according to algorithms employed, and performance attained, maintain a library collection of relevant scientific articles, deliver the database and library to DARPA, and host and conduct contractor meetings.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project are provided by DARPA.

**TITLE:** Theoretical and Experimental Research into Biological Mechanisms Underlying Learning and Memory

**PRINCIPAL**

**INVESTIGATOR:** Leon N. Cooper  
Brown University  
Center for Neural Science  
(401) 863-2585

**R&T PROJECT CODE:** 4426830    **CONTRACT No:** N0001486K0041

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

Detailed objectives include the following: to clarify the dependence of learning on synaptic modification; to elucidate the principles that govern synapse formation or modification, both local factors and global information such as that which may be delivered and/or mediated by neuromodulators; to use principles of organization that can account for observations on a cellular level to construct network models that can compute, and reproduce higher level cognitive acts.

**Approach:**

Approaches include both theory and experiment. Theoretical and experimental consequences of the hypothesis that synapse modification is dependent on local information (in visual cortex) in accordance with theoretical ideas the authors have developed, as well as by global instructions affecting large numbers of synapses and coming from neuromodulators. Various principles that appear to be operating on the cellular level will be used to construct models of higher level functions, including various network models for memory storage, computation and language acquisition.

**Progress:**

Substantial progress made in improvement of storage efficiency in a Hopfield-like model. Correction of storage matrix ("unlearning") yielded 10-fold increase in stored states. Work has begun on a hybrid neural net which integrates Backpropagation with Reilly-Cooper-Elbaum model. Simulations are being developed to benchmark this model against original models. Analysis of experimental data obtained to test BCM model has lead to a new definition of selectivity of visual cortical neurons based on Fourier coefficients of cell tuning curves.

**Report:**

Bear, M. F., & Cooper, L.N. (1989). Molecular mechanisms for synaptic modification in the visual cortex: Interaction between theory and experiment. In M. Gluck & D. Rumelhart (Eds.), Neuroscience and connectionist theory, in press.

**TITLE:** Models of Brain Function

**PRINCIPAL**

**INVESTIGATOR:** Rodney J. Cotterill  
Technical University of Denmark  
Room 262, Building 307

**R&T PROJECT CODE:** 4426600    **CONTRACT No:** N0001489J1882

**CURRENT END DATE:** 01 AUG 1989

**Objective:**

The objective of this conference will be to review the current situation concerning what is known, and what is not known, about the basic functioning of the brain regarding its abilities to memorize, recognize, associate, generalize, and rationalize. This type of meeting has become necessary because of the current massive research activity in the field of neural networks.

**Approach:**

The conference will consist of a number of state-of-the-art invited presentations, poster presentations, and round table discussions. The proceedings of the meeting will be published within 3 months by Cambridge University Press. A transcript of the panel discussions will also appear in the proceedings, including questions from the floor and the responses they elicit.

**Progress:**

This contract is new in FY89.

**TITLE:** Net Technical Assessments of ANN (Neural Network)  
Technologies

**PRINCIPAL**

**INVESTIGATOR:** Robert B. Davidson  
Science Applications International Corp.  
Technology Research Group  
(703) 821-4418

**R&T PROJECT CODE:** a44f003    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of the study is to: (a) evaluate the comparative performance capability of neural networks applied to signal processing tasks (including sonar signal identification, and automatic target recognition), and (b) evaluate the emerging national and international technological capabilities in this area.

**Approach:**

Preparation of a computerized database of neural network technology involves (a) a thorough review and analysis of publications, and technical reports, and (b) host symposia of nationally recognized experts on neural network theory and technology. This team includes several current ONR contractors in ONR's ARI in Biological and Electronic Neural Networks: Leon Cooper, Jerome Feldman, John Hopfield, Carver Mead, and Terrence Sejnowski. Three state-of-the-art symposia will be conducted on the three main topics of the DARPA program: (a) Comparative Performance of Neural Networks, (b) Theory & Modelling, and (c) Hardware Technology.

**Progress:**

This contract is new in FY89.

**TITLE:** Selective Recognition Automata

**PRINCIPAL**

**INVESTIGATOR:** Gerald M. Edelman  
Neurosciences Research Foundation, Inc.  
(212) 570-8975

**R&T PROJECT CODE:** 4426129    **CONTRACT No:** N0001488K0411

**CURRENT END DATE:** 31 JUL 1991

**Objective:**

The major goal of this project is to carry out critical tests of the neuronal group selection theory that will bring selective automata closer to practical application. Specific technical objectives: to account for the regulation of plastic changes in topographic cortical maps, to demonstrate associative learning in selective recognition systems, to study mechanisms for figure-ground discrimination and perceptual constancy in selective systems, to generalize the concept of topographic maps to encompass "cognitive maps" in world-centered coordinate frames, and to represent temporal sequences of events in selective network systems.

**Approach:**

An approach called "synthetic neural modelling" will be applied to the objectives. This approach depends on starting with a coherent theory of brain function and testing that theory by constructing model automata that follow principles of biological evolution and development. A special purpose network simulation device will be designed and constructed to facilitate the research and to begin the investigation of practical devices based on selection principles.

**Progress:**

The PI has constructed simulator modules of the visual system, oculomotor system, somatosensory system, and motor system, incorporating biological self-organizing rules, and a unique mapping system to connect the modules. He has given this system a virtual 4 jointed arm, a foveation system, and tactile sensors on the "hand." This system learned to foveate a moving target, to acquire the target with the arm, and to investigate its tactile properties. A new simulation of visual cortex has been developed based on a model called Reentrant Cortical Integration. The categorization behavior of Darwin III automaton has been compared with human performance.

**Report:**

Finkel, L. H., Reeke, G. N., Jr., & Edelman, G. M. (1989). A population approach to the neural basis of perceptual categorization. In L. Nadel, L. A. Cooper, P. Culicover, & R. M. Harnish (Eds.), Neural connections. Mental computation. pp. 146-179, Bradford Books, MIT Press, Cambridge.

**TITLE:** Intracerebral Neuronal Grafts: Enhanced Cognitive Performance

**PRINCIPAL**

**INVESTIGATOR:** Fred H. Gage  
University of California  
Neurosciences  
(619) 452-2416

**R&T PROJECT CODE:** 4426016    **CONTRACT No:** N0001486K0347

**CURRENT END DATE:** 31 MAY 1989

**Objective:**

A novel application of technology (intracerebral grafting) to determine whether the performance of a normal intact animal can be enhanced by the addition of neural tissue to specific regions of the host animal's brain.

**Approach:**

Basal forebrain cholinergic neurons or brainstem aminergic neurons will be implanted near their principle target regions in the hippocampus and neocortex. Behavioral tests will be used that will allow for assessment of enhanced learning and memory. Complete anatomical analyses of each graft will be conducted in order to determine the extent and importance of host-graft connectivity.

**Progress:**

Neuroanatomical analyses of implants has revealed neurochemical and functional implant-hippocampal connections. Present work is attempting to determine whether these connections result in enhanced performance both in vivo (maze performance) and in vitro (LTP in slices).

**Report:**

Rosenberg, M. B., Friedmann, T., Robertson, R. C., Tuszynski, M., Wolff, J. A., Breakefield, X. O., & Gage, F. H. (1989). Grafting genetically modified cells to the damaged brain: Restorative effects of NGF expression. Science, in press.  
Buzsaki, G., Ponomareff, G., Bagardo, F., Shaw, T., & Gage, F. H. (1988). Suppression and induction of epileptic activity by neuronal grafts. P.N.A.S. 85.

**TITLE:** Training in Methods in Computational Neuroscience

**PRINCIPAL**

**INVESTIGATOR:** Harlyn O. Halvorson  
Marine Biological Laboratory  
(508) 548-3705

**R&T PROJECT CODE:** 442h004    **CONTRACT No:** N0001489J1885

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

The primary aim of the course is to provide the 20 participants with the tools to simulate the functional properties of those neural systems of interest as well as to understand the general advantages and disadvantages of this experimental approach.

**Approach:**

The lectures are presented by the course directors (James Bower & Christof Koch-Caltech) and invited faculty (Paul Adams, Dan Alkon, Richard Andersen, John Hildebrand, John Hopfield, Rudolfo Llinas, John Rinzel, David Rumelhart, Idan Segev, Terrence Sejnowski, David Van Essen, and Christof Von der Malsburg). The computer laboratory provides students with the opportunity to begin simulations of neural systems. The lab will be equipped with loaned Sun graphics work stations running the General Network Simulation System which was created with ONR support by James Bower.

**Progress:**

This contract is new in FY89.



**TITLE:** Studies in Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** John J. Hopfield  
California Institute of Technology  
Department of Chemistry  
(818) 356-6034

**R&T PROJECT CODE:** 4426803    **CONTRACT No:** N0001487K0377

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

To construct model neural networks which can solve some of the computational problems of olfaction; to examine the connections between the model networks and the real olfactory networks; to understand the importance of the time-dependent aspects of olfactory processing. To study the effectiveness of neural networks at Quadratic Match problems; to examine the range of interesting problems which a Quadratic Match computer could do.

**Approach:**

A study of the mathematics of the computations involved, and simulations of appropriate neural networks on conventional computers. In olfaction, important experimental input to the research is required. In studies, experimental data will be obtained by purchasing electronics for data acquisition from real verbal signals.

**Progress:**

(a) Simulations of neural nets have been performed which identify spoken sequences of numbers at 99% accuracy. (b) A dynamical model of the olfactory bulb has been constructed and analyzed mathematically. (c) Self organization of visual cortex is being examined. (d) A molecular device shift register has been developed with a memory density 100-1000 times that of ordinary VLSI technology.

**Report:**

Hopfield, J. J., & Tank, D. (1989). Neural architecture and biophysics for sequence recognition. In J. Byrne & W. Berry (Eds.), Neural models of plasticity. Academic Press.  
Hopfield, J. J., et al. (1988). A molecular shift register based on electron transfer. Science, 241, 817-820.

**Outside Funding:**

This work is currently supported in cooperation with the Electronics Division (Code 1114SE).

**TITLE:** Adaptive Control of Limb Motion by Brains and Robots

**PRINCIPAL**

**INVESTIGATOR:** James C. Houk  
Northwestern University  
Department of Physiology  
(312) 908-8219

**R&T PROJECT CODE:** 4426126    **CONTRACT No:** N0001488K0339

**CURRENT END DATE:** 30 MAY 1990

**Objective:**

The proposal is designed to advance knowledge about how the cerebellum might mediate adaptive feedforward control, and to apply this information to robotics.

**Approach:**

The investigators will conduct computer simulations of motor systems, in the form of simulated neural networks, that are based on the anatomy and physiology of the cerebellum. More specifically, the investigators are interested in the functional and computational significance of the findings that will result from the mapping of mossy-fibre inputs to cerebellar cortex. Consequently, the investigators will develop and simulate networks of neuron-like units whose architectures and roles in motor control are based on anatomical and physiological knowledge.

**Progress:**

The PI has (a) recorded from monkey cerebellum and characterized the sensory and efference copy information in the mossy fibers, (b) in collaboration with C.H. Wu, implemented a model of muscle cross-bridge dynamics and nonlinear feedback, and (c) with A. Barto has implemented an adaptive network model of the cerebellum.

**Report:**

Houk, J. C., Barto, A., Singh, S. P., & Stevens, C. Storage and retrieval of motor programs in the cerebellum. Abstract for Models of Brain Function Conference, Copenhagen, Denmark, 12-16, June 1989.

Houk, J. C. Schema for motor control utilizing a network model of the cerebellum. In D. Z. Anderson (Ed.), Neural information processing systems. New York, NY: Amer. Inst. Physics, 1988, 367-376.

**TITLE:** Dynamic Biophysical Theory for the Role of Hippocampal Neural Networks in the Declarative Memory System

**PRINCIPAL**

**INVESTIGATOR:** Christof Koch  
California Institute of Technology  
Division of Biology  
(818) 356-6855

**R&T PROJECT CODE:** 4426201    **CONTRACT No:** N0001488K0297

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

Koch will develop appropriate algorithms for carrying out hippocampal simulations. One focus will be the detailed biophysical events possibly underlying induction of LTP in dendritic spines and single pyramidal cells. In parallel, the second focus will be a network model of the entire hippocampal structure. The two models will provide an organizational substrate to suggest and generate new biological experiments.

**Approach:**

In collaboration with a second ONR contractor, the PI proposes to begin construction of a viable and testable network-level theory of the nature of the information processing that occurs in mammalian central nervous systems. The theory will combine the best neural modelling techniques with state-of-the-art cellular neurobiological experimentation. This contract represents the higher-level or top-down (computational) approach that will serve to guide the bottom-up (neuroscience) strategy.

**Progress:**

(A) The PI, in collaboration with a 2nd contractor, Dr. Thomas Brown has simulated events occurring at a single synapse on a dendritic spine. NMDA receptors placed in parallel with quisqualate-kainate receptors can produce heterosynaptic LTP, with NMDA currents lasting 100 ms. (B) Computer simulations of associative learning in Hermissenda reveal changes in timing of light-mediated depolarization as a result of changing the activation rate of two potassium channels (I:A and I:Ca-K). An important insight from this study is that changes in the timing of post-synaptic potentials (PSP's) may be as important as an expression for cellular plasticity as changes in the amplitude of the PSP's. (C) Computer analysis using sigma-pi units (higher order nets) as artificial cortical neurons has shown that these units act as smoothly-interpolating look up tables, explicitly storing input-output associations as distinct clusters of synapses.

**Report:**

Koch, C., & Segev, I. (1989). Methods in neuronal modeling: From synapses to networks. Cambridge, MA: MIT Press.

**TITLE:** Analysis and Simulation of a Cortical Network

**PRINCIPAL**

**INVESTIGATOR:** Gary Lynch  
University of California, Irvine  
Center for Neurobiology of Learning and Memory  
(714) 856-4274

**R&T PROJECT CODE:** 442h010    **CONTRACT No:** N0001489J1255

**CURRENT END DATE:** 30 SEP 1991

**Objective:**

The objective is an understanding of the types of learning operations carried out by simple cortical networks. This requires research at four different levels: (1) neurobiology, (2) simulations and mathematical analysis, (3) behavioral neurophysiology (i.e., chronic recording), and (4) behavior.

**Approach:**

Researchers have historically sought to investigate the remarkable memorial capacities of brain by trying to identify physiological, anatomical, or chemical correlates of specific types of behavioral learning. This effort goes in the reverse direction. The PI's first ask how complex sets of physiological variables govern the collective activity of neurons in brain networks, and second if these aggregate activities might produce recognizable behavioral events. Using this strategy, they hope to develop general formulations stated in basic biological terms that relate physiology and anatomy to particular aspects of memory.

**Progress:**

A computer simulation of a mammalian olfactory bulb glomerulus was constructed which included many neural details including: 125 olfactory nerve axonal inputs, 23 mitral/tufted cells, 90 granule cells, and 15 periglomerular cells. Individual cell EPSPs and IPSPs were calculated via non-linear summation of potentials in compartments in mitral/tufted and granule dendrites, through both axo-dendritic and dendro-dendritic simulated synaptic contacts, including realistic activation curves and synaptic delays. The rapidly approaching goal is a sophisticated frequency-to-spatial encoder.

**Report:**

Granger, R., Ambros-Ingerson, J., Anton, P., Whitson, J., & Lynch, G. (1989). Computational action and interaction of brain networks. In S.F. Zornetzer, J. Davis, & C. Lau (Eds.), Introduction to biological and electronic neural networks. New York: Academic Press.

Granger, R., Ambros-Ingerson, J., & Lynch, G. (1989). Derivation of encoding characteristics of layer II cerebral cortex. J. Cognitive Neuroscience, 1:61-89.

**TITLE:** Organization of Large Scale Cortical Network

**PRINCIPAL**

**INVESTIGATOR:** Gary Lynch  
University of California, Irvine  
Center for Neurobiology of Learning & Memory  
(714) 856-4274

**R&T PROJECT CODE:** 4426019    **CONTRACT No:** N0001486K0333

**CURRENT END DATE:** 30 JUN 1989

**Objective:**

Neurophysiological and anatomical experiments will answer questions which will facilitate attempts to design electronic circuits that will incorporate features of the olfactory system. Simulations of this network will provide basis for computer modelling of information storage.

**Approach:**

Approach involves quantifying interconnectivity of olfactory cortical matrix, identifying preferred operating frequencies, examining how the matrix is "read out" by subcortical sites, simulating the matrix as a computer model, and attempting to translate the features of the cortical system into engineering terms with the ultimate goal of constructing novel computer circuitries.

**Progress:**

Contractor has shown the existence of long term potentiation in the behaving animal that matches the behavior displayed in an olfactory memory and discrimination task. New work on NMDA receptors and their role in the formation of memory continues in both intact animals and in vitro (hippocampal slice) preparations.

**Report:**

Lynch, G., Granger, R., Larson, J. & Baudry, M. (1988). Cortical encoding of memory: Hypotheses derived from analysis and simulation of physiological learning rules in anatomical structures. In L. Nadel, L. A. Cooper, P. Culicover, R. M. Harnich (Eds.), Neuronal connections and mental computations. Bradford Books/MIT Press, Cambridge.  
Staubli, U., & Lynch, G. (1987). Stable hippocampal long-term potentiation elicited by "theta" pattern stimulation. Brain Res. 435, 227-234.  
Staubli, U., Larson, J., Baudry, M., Thibault, O., & Lynch, G. (1988). Chronic administration of a thiol-proteinase inhibitor blocks long-term potentiation of synaptic responses. Brain Res. 444, 153-158.

**TITLE:** Intelligent Controls Research Using Dextrous Robotic Hands and Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** Robert A. McLauchlan  
Texas A&I University  
Civil and Mechanical Engineering Department  
(512) 595-2003

**R&T PROJECT CODE:** dipn131    **CONTRACT No:** N0001489J1298

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

The DOD Defense-University Research Instrumentation Program was designed to improve the capabilities of U.S. universities to conduct DOD-relevant research by supporting the purchase of major equipment critical to the conduct of that research. This effort helps purchase equipment that supports research in advanced robotics using neural networks as intelligent controllers.

**Approach:**

This proposal requests funds for the acquisition of dextrous robotic hands and neurocomputing systems. These systems will be integrated with existing and proposed robotics and controls equipment to create a robotic hands and neural networks laboratory for performing intelligent controls research. Three ongoing projects will use this laboratory to investigate basic issues in robotic systems, automated manufacturing, and machine intelligence. These projects include investigations of: (1) dynamics, sensor and control issues pertinent to smart (a) robotic hands for grasping and manipulation, (b) multiple arm/hand systems for complex assembly operations. (2) neural network sensor integration and intelligent control applications ; and (3) use of expert systems and neural networks to analyze flexibility in automated manufacturing cells.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by the Defense-University Research Instrumentation Program.

**TITLE:** Robust Planning and Control Using Locally Generalizing  
Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** Thomas Miller  
University of New Hampshire  
Dept. of Electrical and Computer Engineering  
(603) 862-1326

**R&T PROJECT CODE:** a44e002    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this research is to expand the theoretical understanding of neural network based learning control systems, including hierarchical learning control structures.

**Approach:**

The research consists of both theoretical modelling studies of system performance in learning control systems, and experimental studies using various robotic systems. Mathematical analyses will be conducted of: (a) convergence properties of control systems during continuous on-line training, (b) history dependence of neural network dynamical systems, (c) the robustness of learned planning systems for trajectory planning in incompletely trained models, and (d) utility functions such as minimum time, minimum energy, etc. for dynamical systems with constraints. Computer simulations and experiments on a robot biped will be conducted to study reinforcement learning during efficient biped walking on horizontal or sloped surfaces. Theoretical analyses of the nonlinear control system properties of neural networks will be conducted. Fault tolerance analyses will be made using techniques from information theory, identifiability of system input-output, and diophantine approximation theory.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** A Computational Analysis of Properties and Limitations  
of Neural Networks: Toward New Parallel Architectures

**PRINCIPAL**

**INVESTIGATOR:** Tomaso Poggio  
Massachusetts Institute of Technology  
Artificial Intelligence Laboratory  
(617) 253-5230

**R&T PROJECT CODE:** a44e001    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objectives of this research are (1) to establish the relations between some of the most interesting neural network architectures (eg. backpropagation nets) and classical approximation and estimation theory, (2) to leverage this understanding by proposing new architectures, and obtaining estimates of comparative performance, and (3) to demonstrate the new algorithms on real vision problems, in particular assessing quantitative improvements that can be obtained in Image Understanding systems by integrating estimation techniques of the neural network type into an existing Vision Matching system.

**Approach:**

The approach consists of two parts. In the first part the investigators will consider the problem of learning from the point of view of approximation theory and establish relations among the different techniques. From this point of view, a backpropagation net is one of many different approximation models. In particular, we want to understand the approximation properties of certain specific neural nets and their precise relationship to models such as regularization, splines, radial basis functions and MRF's. In addition they will develop new, more powerful approaches for generalizing from a set of examples. In the second part, the issue of sample complexity will be examined. Sample complexity of a problem is a measure of the size of the sample set that is needed. The results of this analysis will permit development of new ways of dealing with a limited number of samples by exploiting "a priori" constraints and knowledge. In both parts, analysis will be supplemented with computational experiments in the domain of vision.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.



**TITLE:** Experimental and Computational Models of Neural Network Learning

**PRINCIPAL**

**INVESTIGATOR:** Terrence J. Sejnowski  
The Salk Institute  
(619) 453-4100

**R&T PROJECT CODE:** 4426822    **CONTRACT No:** N0001489J1766

**CURRENT END DATE:** 31 MAR 1991

**Objective:**

The P.I. has developed a combined in vitro hippocampus-entorhinal cortex slice preparation which includes both the intact hippocampal trisynaptic circuit, and input/output sites in entorhinal cortex. Studies in this preparation will focus on network interactions between cellular groups and how these are altered by the induction of long-term changes in cellular excitability. These studies will be combined with computer simulation of a neuronal network with connections faithful to hippocampal anatomy and processing units emulating important characteristics of hippocampal neurons.

**Approach:**

To decipher information storage and retrieval in the brain the PI will use the tools and techniques for simulating large parallel networks of processing units that have been developed for connectionist network models and apply them to the brain areas that are known to have roles in learning and memory. Not enough is known to completely constrain these models, so additional constraints will be sought by performing experiments on brain tissue that critically test assumptions and predictions of the models.

**Progress:**

The PI examined the conditions under which the stimulation of hippocampal pathways could produce long-term depression or potentiation of synaptic strengths, depending upon the pattern of stimulation. When strong and weak inputs were applied in phase an associative LTP was observed, but when they were applied out of phase an associative long-term depression (LTD) was obtained. The NMDA receptor antagonist AP5 blocked the induction of LTP but had no effect on the associative LTD. Hence, the induction of associative LTD appears to involve mechanisms different from associative LTP.

**Report:**

Sejnowski, T. J., & Stanton, P. K. (1989). Anti-Hebbian synaptic plasticity and storage of covariance in the hippocampus. In S. Zornetzer, J. Davis, & C. Lau (Eds.), Introduction to neural and electronic networks. Academic Press.

Stanton, P. K. & Sejnowski, T. J. (1989). Associative long-term depression in the hippocampus: Evidence for anti-Hebbian synaptic plasticity. Nature, in review.

**TITLE:** The Organization of Memory

**PRINCIPAL**

**INVESTIGATOR:** Larry R. Squire  
University of California, San Diego  
Department of Neuroscience  
(619) 453-7500

**R&T PROJECT CODE:** 4426023    **CONTRACT No:** N0001486K0738

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

Work is directed towards understanding how memory is organized in the brain. Human studies will determine what kinds of procedural knowledge are acquired when learning occurs, how long it lasts, and how (if at all) such knowledge influences or otherwise interacts with conscious remembering. Primate experiments are directed towards defining a structure and physiological mechanisms which does not itself store memory but which serves to address, organize, or otherwise support memory storage sites for a limited period after learning.

**Approach:**

Human work will initially proceed by taking autonomic measures (skin conductance responses) during learning and retention sessions in amnesic patients and control subjects. It will be determined whether these or other measures taken at the same time are intact, whether they convey information about otherwise forgotten material, and whether they influence conscious remembering. The monkeys will be given small, neurosurgical lesions to damage or disconnect structures within the medial temporal region of the brain. Behavioral tasks will precisely define the nature of the memory deficit.

**Progress:**

The PI has continued to relate his primate models to the human clinical data. Medial temporal lesions impair memory on a variety of tasks sensitive to human amnesia. Work continues on a project to specifically remove layer CA1 to mimic the memory deficits described earlier by the PI in his work with patient RB. Memory models based on cognitive neuroscience data are also undergoing development.

**Report:**

Zola-Morgan, S., Squire, L. R., & Amaral, D. G. (1989). Lesions of the hippocampal formation by not lesions of the fornix or the mammillary nuclei produce long-lasting memory impairment in monkeys. J. Neuroscience, 9, 898-913.

**TITLE:** Functional Anatomy of Neocortical-Hippocampal Circuits

**PRINCIPAL**

**INVESTIGATOR:** Timothy J. Teyler  
Northeastern Ohio University  
Neurobiology Program  
(216) 325-2511

**R&T PROJECT CODE:** 4426017    **CONTRACT No:** N0001486K0664

**CURRENT END DATE:** 31 JUL 1989

**Objective:**

The goal of this series of experiments is to delineate the nature of the neocortical to hippocampus communication, to determine their topological parameters and ability to elicit long term potentiation at the level of the hippocampus. The objective is theory-driven and involves understanding how experiential information is processed in a massively parallel fashion.

**Approach:**

Electrophysiological studies will determine the functional relationship between neocortex and hippocampus and will be complemented by plasticity studies wherein tetanic stimulation will be applied to the neocortical locus to determine if LTP is produced in hippocampus. Neuroanatomical research will be used to validate the neurophysiological studies.

**Progress:**

The PI has identified various forms of neocortical long term potentiation (LTP) that possess different laminar locations and involve various neurotransmitters. Work continues on characterizing topographic relations between hippocampus and neocortex.

**Report:**

Grover, L. M., & Teyler, T. J. Effects of extracellular K concentration and post-synaptic membrane potential on Ca-induced potentiation in area CA1 of rat hippocampus. Brain Research, (in press).

Teyler, T. J. (1989). A model of associative interactions mediated by NMDA activation. In W. C. Abraham (Ed.), Memory mechanism: A tribute to G. V. Goddard. Hillsdale, NJ: Lawrence Erlbaum

**TITLE: A Biological Neural Network Analysis of Learning and Memory**

**PRINCIPAL**

**INVESTIGATOR:** Richard F. Thompson  
University of Southern California  
Department of Psychology  
(213) 743-2240

**R&T PROJECT CODE:** 4426001     **CONTRACT No:** N0001488K0112

**CURRENT END DATE:** 31 JAN 1991

**Objective:**

A three year research plan includes three levels of complexity within which the PI plans to model the critical neuronal circuitry; each level builds cumulatively on the previous levels. Level I concentrates on single pathway models of conditioning involving the IO, deep nuclei, and other brain structures. These models will address phenomena at a trial-level of detail comparable to the Rescorla-Wagner model. Level II integrates level I into real-time models of conditioning which address effects of ISI manipulations and adaptive delay of the CR. Level III incorporates the previous levels into multiple-pathway models involving more complete descriptions of the stimulus-response pathways.

**Approach:**

Approach involves a detailed empirical characterization of the properties of the essential neurobiological network and a quantitative computational modeling of the network that incorporates all the known properties and constraints of the actual biological network. At the behavioral level the PI has adopted the Rescorla-Wagner (1972) model, an influential mathematical model of associative learning. At the biological level, the neural system shown to be responsible for the production of the classically conditioned nictitating membrane response will provide the experimental test bed.

**Progress:**

Empirical work has shown 1) key role of mossy fiber activation by CS in learning involving cerebellum, 2) the red nucleus is efferent from site of memory trace but is key in modulation of effective US. Theoretical work has integrated behavioral, computational and biological models of classical conditioning.

**Report:**

Donegan, N. H., Gluck, M. A., & Thompson, R. F. (1988). Integrating behavioral and biological models of classical conditioning. In R. D. Hawkins & G. H. Bower (Eds.), Computational models of learning in simple neural systems. New York: Academic Press.  
Thompson, R. F. (1988). The neural basis of basic associative learning of discrete behavioral responses. Trends in Neuroscience, 11(4), 152-155.

**TITLE:** Analysis of Neural Network Issues: Scaling, Enhanced Nodal Processing, Comparison with Standard Classification Techniques

**PRINCIPAL**

**INVESTIGATOR:** Gregg Wilensky  
R & D Associates  
(213) 822-1715

**R&T PROJECT CODE:** a44f004    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective is to obtain, both from the literature and by original computer simulations, benchmark data comparing different types of neural networks with traditional pattern recognition procedures. An important component of this research is the analysis of the effects of scaling up the size of these nets and adding complex nodes.

**Approach:**

The approach will include extracting current algorithms and implementations of neural nets, and benchmark data, in order to construct a database. This will serve as a starting point for original computer simulations. Practical measures of problem complexity will be developed in order to compare the scaling and convergence properties of different neural networks. Neural nets will be compared with traditional classification techniques using identical test problems, and evaluated, based on code development time, speed of operation, learning rate, and performance of correct classifications.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**BIOLOGICAL INTELLIGENCE**

**CHEMICAL MODULATORS OF  
INFORMATION PROCESSING**

*157/158*

**TITLE:** Neuroregulators and Stress: Effects of Neuropeptides and Their Analogues

**PRINCIPAL**

**INVESTIGATOR:** Jack D. Barchas  
Leland Stanford Junior College  
Department of Psychiatry  
(415) 723-7522

**R&T PROJECT CODE:** 4426750    **CONTRACT No:** N0001486K0251

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

Operational situations expose Navy and Marine Corps personnel to stressors varying in severity. The body's response involves biochemical and physiological mechanisms not completely understood. This research will explore the role of neuropeptides in the stress response.

**Approach:**

To perform a series of experiments to determine chemical and pharmacological properties of novel neuropeptides which have the C-terminal amide structure. Work will focus on peptide HI, searching for sequence related agonists and antagonists with a novel approach based on multiple solid phase peptide synthesis and radio receptor techniques.

**Progress:**

In a series of studies on the peptide pancreastatin, RIA and immunohistochemical results indicate the presence of it or related peptides in the brain, pituitary, and adrenal, suggesting a possible neuroendocrine role for this peptide. Isolation of the gene is in progress after which studies of messenger RNA and peptide regulation can be performed.

**Report:**

Tecott, L. H., Barchas, J. D., & Ebermine (1988). In situ transcription: Specific synthesis of complementary DNA in fixed tissue sections. Science, 240:1661-1664.

**TITLE: Experimental Investigations of Synaptic Learning Rules  
in the Cerebral Cortex**

**PRINCIPAL**

**INVESTIGATOR:** Mark F. Bear  
Brown University  
Center for Neural Science  
(401) 863-2070

**R&T PROJECT CODE:** 4426137     **CONTRACT No:** N0001488K0756

**CURRENT END DATE:** 14 SEP 1991

**Objective:**

The effects of high-frequency electrical stimulation of white matter on the amplitude of cortical EP's will be studied as several parameters are varied systematically. Other parameters include GABAergic inhibition, presence or absence of the modulatory substances acetylcholine and norepinephrine, relative effectiveness of NMDA and non-NMDA receptors, and effects of prior visual deprivation. The objective is to formulate a set of rules that govern whether a burst of presynaptic activity leads to a lasting increase or decrease in synaptic strength.

**Approach:**

Synaptic modifications have been observed directly in the developing visual cortex of behaving kittens. Critical variables appear to be the presence or absence of extrathalamic modulatory inputs, the level of network inhibition, the amount of stimulus-driven excitatory presynaptic activity, the concurrent level of evoked post-synaptic depolarization, and the recent history of neuronal activity. In the proposed experiments, a reduced preparation of the visual cortex, the in vitro brain slice, will be used to elucidate the precise contributions of each of these variables.

**Progress:**

Specificity of the ability of the NMDA receptor antagonist APV to disrupt visual cortical plasticity. Brief periods of binocular deprivation are sufficient to reduce NMDA stimulated Ca++ uptake. Striking correlation between the ability of non-NMDA amino acids to stimulate phosphatidyl inositol turnover and the susceptibility of visual cortex to monocular deprivation.

**Report:**

Bear, M. F., & Cooper, L. N. Molecular mechanisms for synaptic modification in the visual cortex: Interaction between theory and experiment. In M. Gluck, & Rumelhart (Eds.), Neuroscience and connectionist theory, in press.



**TITLE:** Computational Analyses of a Neural Network for  
Conditioned Taste Aversions.

**PRINCIPAL**

**INVESTIGATOR:** Kathleen C. Chambers  
University of Southern California  
Department of Psychology  
(213) 743-7762

**R&T PROJECT CODE:** 442h003    **CONTRACT No:** N0001489J1296

**CURRENT END DATE:** 14 DEC 1991

**Objective:**

The objective of this research is to understand the processes of learning and memory by analyzing how the brain codes, stores and retrieves information. The PI will integrate two approaches to the study of learning and memory: an empirical neurobiological approach and a computational modeling approach. The modelling approach will incorporate all known neurobiological evidence that includes the properties and constraints of the biological system. The neurobiological studies will be impacted by the predictions about neural functioning that stem from the computational modeling.

**Approach:**

The research is divided into two approaches, a biological systems approach and a computational model approach. The first approach will empirically determine the neural areas that are necessary for and that modulate learning, retention, and extinction of conditioned taste avoidance (CTA). The second approach will develop computational models for the neural activity of those areas, i.e., the patterns of activity of a given known relay in the essential circuitry for CTA that change as a result of learning.

**Progress:**

This contract is new in FY89.

**TITLE:** Probing The Molecular Mechanisms of Associative Learning with Monoclonal Antibodies

**PRINCIPAL**

**INVESTIGATOR:** John F. Disterhoft  
Northwestern University  
Department of Cell Biology & Anatomy  
(312) 908-7982

**R&T PROJECT CODE:** 4426134    **CONTRACT No:** N0001488K0399

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

To learn more about the macromolecules that modulate the electrophysiological state and function of neurons. In collaboration with Moskal at Einstein the PI will help produce and test a series of monoclonal antibodies which may be ideal probes to perturb function and identify the macromolecules involved with associative learning. Testing will include both in vivo (LTP in hippocampal slices) and in vitro (behavioral classical conditioning) preparations.

**Approach:**

The PI will evaluate the behavioral effect of antibodies on hippocampal neurons in the behaving animal and in brain slices. Intracellular recordings will be made in hippocampal sections to biophysically evaluate the effect of each monoclonal antibody on resting activity and excitability of the cells. In awake animals, the effect of various monoclonals during acquisition of a conditioned response will be observed.

**Progress:**

The PI has gained definitive evidence that trace eye-blink conditioning paradigm in rabbit is dependent upon the hippocampus for successful acquisition when a 500 ms trace period intervenes between a 100 ms tone CS and the corneal air puff US. Preliminary evidence has been obtained that monoclonal antibody B6E11 (provided by Moskal) which binds to hippocampal neurons, may impair behavioral learning acquisition in the same fashion as hippocampal lesions. NMDA mediated transmission may be required for associative learning, as well as LTP.

**Report:**

Moyer, J. R., Jr., Deyo, R. A., & Disterhoft, J. F.  
Hippocampal lesions impair trace eye blink conditioning in rabbits. Behavioral Neuroscience. In press.  
Disterhoft, J. F., et al. Associative learning in aging rabbits is facilitated by nimodipine. In W. Gispen & J. Traber (Eds.), Nimodipine and central nervous functions-new vistas. Stuttgart: Schattauer, in press.

**TITLE:** Glucose Effects on Human Memory and on Neurobiological Memory Substrates

**PRINCIPAL**

**INVESTIGATOR:** Paul E. Gold  
University of Virginia  
Department of Psychology  
(804) 924-0685

**R&T PROJECT CODE:** 4426140    **CONTRACT No:** N0001489J1216

**CURRENT END DATE:** 30 NOV 1991

**Objective:**

The work will assess pharmacological approaches to enhance memory in humans. The proposed studies will be performed on healthy young adult volunteers and will examine dose-response curves, several memory tasks, and questions of storage vs. retrieval.

**Approach:**

Specifically, the PI will 1) test the possibility that glucose injections, including peripheral, central, and very localized injections, can control the establishment of long-term potentiation at both the physiological and structural levels; and 2) evaluate the effects of glucose on human memory.

**Progress:**

The PI has: (1) Investigated interactions of glucose with functions of several neurotransmitter systems, including acetylcholine, opioids, and glutamate. The findings indicate that glucose augments cholinergic functions, impairs opioid functions, and does not interact with NMDA functions. (2) Investigated the effects of glucose on LTP in the dentate gyrus, in the presence of antagonists. The findings indicate that glucose and cholinergic antagonists do not influence LTP in dentate. A novel NMDA antagonist impairs LTP and the impairment is not reversed by glucose. (3) Investigated glucose effects on human memory. Glucose administration enhances some (e.g., long-term declarative memory) but not all aspects of memory, and does not influence other cognitive elements (e.g., cognitive performance, attention).

**Report:**

McGaugh, J. L., & Gold, P.E. (1989). Hormonal modulation of memory. In R. Brush & S. Levine (Eds.). Psychoendocrinology. New York, Academic Press, pp. 305-339.

Gold, P.E. (1989). Acute glucose treatment and chronic glucose regulation therapy: Potential for enhancing cognitive functions in aging. In N. Shock, et al. (Eds.), The potential for nutritional modulation of aging processes. Westport, CT, Food and Nutrition Pr.

**TITLE:** Three-Dimensional Organization of Circuits in the  
Extrapyramidal Motor System

**PRINCIPAL**

**INVESTIGATOR:** Philip M. Groves  
University of California, San Diego  
Department of Psychiatry  
(619) 534-3736

**R&T PROJECT CODE:** 4426637     **CONTRACT No:** N0001489J1254

**CURRENT END DATE:** 31 OCT 1991

**Objective:**

The experimental work funded by this action will provide insights into the neostriatal circuitry underlying the guidance and execution of voluntary movement. These insights may be used to build a new generation of robotic devices.

**Approach:**

Using computer-assisted three-dimensional reconstruction, the PI will continue to analyze the 3-D organizational framework for neostriatal motor circuitry.

**Progress:**

The neostriatum (basal ganglia) is known to be important in motor control. This structure was once considered to be homogeneous, but the PI has shown that regions differing in neurochemical composition can be identified within this area. Discrete patches have been observed which are low in AChE, and which overlap patches that stain intensely for the peptide enkephalin. These patch zones exhibit different inputs and outputs than non-patch regions. The 3-D distribution of enkephalin patches in neostriatum was performed using computer aided systems employing depth cuing. The reconstructions revealed that enkephalin patches form a lattice structure enclosing tubes of matrix. The lattice patterns were similar across animals, and were suggestive of highly organized interactions between patch and matrix.

**Report:**

Groves, et al. (1988). Three dimensional pattern of enkephalin-like immunoreactivity in the caudate nucleus of the cat. Journal of Neuroscience, 8:892-900.  
Groves, et al. (1988). Dopamine regulation of neostriatal input/output relations. In A. Liss. Progress in catecholamine research. New York, pp. 124-129.

**TITLE:** The Role of Lamination in Neocortical Function

**PRINCIPAL**

**INVESTIGATOR:** Harvey J. Karten  
University of California, San Diego  
School of Medicine  
(619) 534-4938

**R&T PROJECT CODE:** 4426131    **CONTRACT No:** N0001488K0504

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

A major goal of this project is to investigate the nature and benefits of lamination of cortex. In the avian brain, cortical equivalent populations ("clonal clusters") of neurons occur in non-laminated configurations, but have similar characteristics in their connections, transmitters and cell morphology. The clonal nature of the avian telencephalon lends itself to both physiological and biochemical analyses not readily accomplished with mammalian neocortex. In the proposed experiments, the PI will collect detailed information about the clonal type of organization, particularly, within the avian visual system.

**Approach:**

(1) The anterograde and retrograde transport of several tracers will be used to explore the microcircuitry of cortical equivalent neurons in the absence of lamination. (2) The transmitters/peptides/receptors in these cortical equivalent populations will be studied using immunochemistry and in situ hybridization histochemistry. (3) The morphological characteristics of neurons in these populations will be studied using the single-cell filling technique.

**Progress:**

Research in this lab addresses the contribution of cortical lamination to the computational capability of sensory cortex. The PI is examining the cellular chemistry, connectivity, and physiology of visual forebrain regions in species where the functional equivalent of neocortex consists of clusters of neurons rather than separate layers of cortex. He has shown the patterns of connectivity between these clusters and shown that the clusters consist of biochemically distinct neuronal populations. These data are providing additional support for the hypothesis that the elaboration of mammalian, laminated cortex consisted of the intermingling of distinct cell populations.

**Report:**

Shimizu, T. & Karten, H. J. (1989). Computational equivalence with changing morphology. Submitted.  
Shimizu, T., Woodson, W., & Karten, H. J. (1989). Intratelencephalic connections of the ectostriatum in birds. Soc. Neurosci., submitted.

**TITLE:** Analysis of Neural Systems Involved in Modulation of Memory Storage.

**PRINCIPAL**

**INVESTIGATOR:** James L. McGaugh  
University of California, Irvine  
Department of Psychobiology  
(714) 856-5401

**R&T PROJECT CODE:** 4426815    **CONTRACT No:** N0001487K0518

**CURRENT END DATE:** 31 DEC 1990

**Objective:**

The objective is to increase understanding of the brain systems involved in the processing of newly acquired information, and of the key brain structures and processes underlying the modulation of memory storage.

**Approach:**

NMDA-induced lesions in specific nuclei in the amygdala will be performed to determine the specific brain regions and neurotransmitters involved in the modulation of memory storage.

**Progress:**

Experimental evidence has been obtained that lesions of the amygdala do not impair the retention of long-term memory, but the amygdala appears to be part of a system which serves to modulate memory storage at sites other than the amygdala. Work is continuing on the role of activation of NE receptors.

**Report:**

Introini-Collison, I. B., & McGaugh, J. L. (1988). Modulation of memory by post-training epinephrine: Involvement of cholinergic mechanisms. Psychopharmacol, 94:379-385.  
McGaugh, J. L., Introini-Collison, I. B., & Nagahara, A.H. (1988). Memory enhancing effects of post-training naloxone: Involvement of B-noradrenergic influences in the amygdaloid complex. Brain Res. 446:37-49.

**TITLE:** Learning and Memory Enhancement by Neuropeptides

**PRINCIPAL**

**INVESTIGATOR:** Rita B. Messing  
University of Minnesota  
Department of Pharmacology  
(612) 625-5960

**R&T PROJECT CODE:** 4411018    **CONTRACT No:** N0001486K0407

**CURRENT END DATE:** 30 JUN 1989

**Objective:**

Organotins are found throughout the environment, but as yet little is known about the mechanisms by which they exert their toxic effects on man or about possible treatment. They are of great interest to the Navy since organotins are a major active component of anti-fouling agents. The technical objective of this program is to better understand their mechanism of action in producing human cognitive dysfunction.

**Approach:**

Because trimethyltin (TMT) produces relatively specific, dose-related damage, rats treated with TMT are a useful model system for assessing cognitive, and related biochemical effects of varying degrees of pathology in hippocampus and related structures. To assess learning/memory impairment in TMT-treated rats, the P.I. uses a delayed reinforcement autoshaping procedure which incorporates features of both classical and operant conditioning paradigms.

**Progress:**

Rats treated with TMT or a mixed ganglioside preparation (given to determine possible therapeutic effect in TMT-treated rats) have decreased concentrations of hippocampal glucocorticoid receptors, which may be related to cognitive impairments. Interestingly, TMT-treated rats have elevated levels of glial fibrillary acidic protein (GFAP), an indication of the cytotoxicity produced by this compound. Rats treated with gangliosides, which induce a cognitive impairment but no cell death, have normal levels of GFAP, but still exhibit the decrease in corticosteroid binding. Thus, this decrease is probably independent of hippocampal cell death, and may be a down regulation.

**Report:**

Gerbec, E. N., Messing, R. B., & Sparber, S. B. (1988). Parallel changes in operant behavioral adaptation and hippocampal corticosterone binding in rats treated with trimethyltin. Brain Research, 460, 346-351.  
Messing, R. B., Bollweg, G., Chen, Q., & Sparber, S. B. (1988). Dose-specific effects of trimethyltin poisoning on learning and hippocampal corticosterone binding. Neurotoxicology, 9, 491-502.

**TITLE: Probing the Molecular Mechanisms of Associative Learning with Monoclonal Antibodies**

**PRINCIPAL**

**INVESTIGATOR:** Joseph R. Moskal  
Albert Einstein College of Medicine  
Department of Neurosurgery  
(212) 920-4328

**R&T PROJECT CODE:** 4426133     **CONTRACT No:** N0001488K0430

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

Generate anti-hippocampal antibodies and evaluate their effect on trace eye blink conditioning. Generate new monoclonal antibodies that will be useful probes to continue to study structure-function relationships between cell-surface macromolecules and synaptic plasticity.

**Approach:**

Three sources of immunogens are used to generate new panels of antibodies. 1) freshly micropunched CA1 from rabbit hippocampus, 2) membranes from synaptosomes prepared from CA1 of trace-conditioned rabbits, and 3) a phosphorylated glycoprotein fraction obtained from synaptic membranes isolated from CA1 of trace-conditioned rabbits. Upon generation of each panel of antibodies, screening will be performed in order to identify those monoclonals that are IgG's and recognize characterisable, cell-surface antigens, found on hippocampal neurons. These antibodies will then be evaluated behaviorally and neurophysiologically by Disterhoft at Northwestern.

**Progress:**

The PI has generated a number of new anti-hippocampal monoclonals including one which behaves like glycine with respect to NMDA receptors and stimulates formation of LTP. The development of antibodies to the NMDA receptor is a step toward the purification, functional reconstitution, and gene cloning of the NMDA receptor. This effort is aimed at elucidating the molecular underpinnings of synaptic plasticity.

**Report:**

Moskal, J. R., et al. Intracerebral administration of a monoclonal antibody to hippocampal dentate gyrus elevates phasic activity during activated sleep in neonatal rats. Submitted to Brain Research.

Moskal, J. R., et al. (1989). Glycine-like modulation of NMDA receptors by a monoclonal antibody that enhances long-term potentiation. Soc. Neuroscience.



# **BIOLOGICAL INTELLIGENCE**

## **NEURAL PROCESSING OF SENSORY INFORMATION**

169/170

**TITLE:** The Use of High Order Neural Networks for Sonar Signal Discrimination

**PRINCIPAL**

**INVESTIGATOR:** Dennis J. Adams  
Loral Defense Systems - Akron  
(216) 796-9791

**R&T PROJECT CODE:** a44b002    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

Development and performance evaluation of adaptive, hybrid high order neural nets using signal processing functions optimized for extracting unique features of acoustic transients. This research will lead to the development of hierarchical neural net signal processing architectures optimized for classifying acoustic transients.

**Approach:**

The research approach is to first examine several unconventional signal processing functions (eg. generalized Fourier transforms such as Fourier Bessel or Fourier Laguerre transforms, maximum entropy methods, or fractal dimension estimators). This signal processing is designed to form new representations of the input signal which emphasize features that distinguish specific acoustic transients, while remaining relatively immune to variations due to source and propagating path inconsistencies. The output of this preprocessing would then be input to a set of high order neural nets (functional-link nets). These nets will be used for both supervised and unsupervised learning to discover the best representation for each transient type. Once this signal representation has been determined, a hierarchical, hybrid system will use these neural nets to process the data provided by DARPA and ONR, and classify the acoustic transients within this data.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Spatial Coding by Posterior Parietal Neurons

**PRINCIPAL**

**INVESTIGATOR:** Richard A. Anderson  
Massachusetts Institute of Technology  
Department of Brain and Cognitive Sciences  
(617) 253-5773

**R&T PROJECT CODE:** 442g004    **CONTRACT No:** N0001489J1236

**CURRENT END DATE:** 14 DEC 1991

**Objective:**

The objective is to deduce the coding of coordinate transformations in parietal cortex. A long standing question regarding the source of the eye position signal will be addressed by determining experimentally whether it is derived from efference copy or proprioceptive inputs. Computational models will be made progressively more complex by adding circuit details of known brain structures.

**Approach:**

A combination of physiological and computational techniques will be used in a series of experiments to pursue the question of how spatial transformations are accomplished in the posterior parietal cortex. The first series of experiments will determine whether head as well as eye position signals gate the visual responses of area 7a neurons, thus producing a coding for location in body-centered as well as head-centered coordinates. The second series of experiments will involve studies of 2-dimensional spatial tuning to examine the third dimension of depth by testing cells for vergence and disparity signals.

**Progress:**

This contract is new in FY89.

**TITLE:** Confocal Laser Scan Imaging System for Hair Cell  
Biophysics and Auditory Neural Networks

**PRINCIPAL**

**INVESTIGATOR:** William E. Brownell  
The Johns Hopkins University  
Otolaryngology - Head & Neck Surgery  
(301) 955-3877

**R&T PROJECT CODE:** dipn128    **CONTRACT No:** N0001489J1365

**CURRENT END DATE:** 14 DEC 1989

**Objective:**

The DOD Defense-University Research Instrumentation Program was designed to improve the capabilities of U.S. universities to conduct DOD-relevant research by supporting the purchase of major equipment critical to the conduct of that research. This effort helps purchase equipment that supports research in neural networks, auditory neurobiology, and biosensors.

**Approach:**

The requested confocal laser scan imaging system improves the signal to noise ratio in light microscopy to the point that cellular organelles with micrometer dimensions can be resolved in living samples. This permits the dynamic structural analysis of cells and reveals 3-dimensional features with greater clarity. An interdisciplinary team of investigators will utilize this instrument to enhance investigations on the biophysics of hair cells, and the organization of neural networks involved in processing auditory information. In one series of experiments the microscope will be used to make high resolution measurements of cytoplasmic and organelle displacements during electrically evoked outer hair cell shape changes, and the fluorescence capabilities will be used with voltage and ion sensitive dyes to measure the membrane channel properties of hair cells. In the second series of experiments, in vitro brain slice recordings will be used to explore the dynamics of information processing the auditory brainstem at the network, cellular, and subcellular levels.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by the Defense-University Research Instrumentation Program.

**TITLE:** Neural Network Models for Parallel Visual Processing

**PRINCIPAL**

**INVESTIGATOR:** George L. Gerstein  
University of Pennsylvania  
Department of Physiology  
(215) 898-8752

**R&T PROJECT CODE:** 4426825    **CONTRACT No:** N0001487K0766

**CURRENT END DATE:** 31 AUG 1990

**Objective:**

Computational rules are being defined from computer vision algorithms whose overall output replicates human psychophysical performance in preattention scene segmentation. The research proposed here is the investigation of neural net models capable of performing the same computations as the computer vision algorithms. The development of such models is essential to further neurobiological studies and machine architecture development.

**Approach:**

To construct and simulate networks of neuronal assemblies which are capable of performing a class of visual computations that deal with texture. The network formalism is influenced and constrained by an area of mathematics describing Gabor filters and neurophysiological data derived from experiments on the mammalian visual system.

**Progress:**

The PI has (1) described an algorithm which uses amplitude distributions of a class of filters found to be good models for simple cells in primary visual cortex, in order to estimate the orientation of inclined textured planar surfaces relative to an observer or camera; (2) used neural network models to predict a new type of receptive field for visual neurons which would allow a human to determine its orientation relative to a textured surface; (3) tested his "gravitational" transformational tool on real data from respiratory neurons, and finds the theoretically predicted sensitivity in detecting neuronal interactions, and (4) demonstrated that dynamic behavior in observed neuronal assemblies can result from either dynamic synapses or activity in a pool of neurons. The degree of synchrony in the neuron pool is an important parameter in producing the dynamic organization among the observed neurons.

**Report:**

Turner, M. R., Bajcsy, R., & Gerstein, G. (1989). Estimation of textured surface inclination by parallel local spectral analysis. Int. J. of Computer Vision, submitted.  
Lindsey, B., Shannon, R., Gerstein, G. (1989). Gravitational representation of simultaneously recorded brainstem respiratory neuron spike trains. Brain Research, 483, 373-378.

**TITLE:** Neural Nets for DOD Communications and Sensor Signal Processing

**PRINCIPAL**

**INVESTIGATOR:** Morgan Grover  
Defense Group Inc.  
(213) 394-8599

**R&T PROJECT CODE:** a44f006    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objectives of the research are: (1) to define and technically characterize a range of important DOD sensor and communications signal processing functions which could be enhanced by emerging neural net technologies, (2) to conduct digital simulations of specific applications, and (3) to identify potential hardware methods and additional neural net research needed for full-scale implementation.

**Approach:**

A comprehensive data base will be developed of priority DOD missions in pre-output signal processing which might be enhanced by neural net methods. These applications will be taken from the areas of: (1) digital communications, (2) radar sensors, (3) sonar sensors, (4) laser systems, and (5) passive optical systems. Two important applications will be selected, one in communications, and one in sensor systems. For these applications digital simulations will be conducted using multilayer neural networks appropriate for the application, including training sequences, evaluation of error rates, retraining after system perturbation, and comparison with alternative training procedures. Based upon these results probable neural network architectures will be defined in greater detail, including quantitative estimates of network size and speed, and potential approaches for hardware implementation identified

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Application and Validation of Neural Network  
Technology

**PRINCIPAL**

**INVESTIGATOR:** Thomas Haley  
Naval Underwater Systems Center  
Department of the Navy  
(401) 841-2206

**R&T PROJECT CODE:** 442h002    **CONTRACT No:** N0001489WX24061

**CURRENT END DATE:** Not available

**Objective:**

Validation of neural network technology on sonar classification tasks, identification of best neural net algorithms, development of algorithms that extract classification clues from raw detection data.

**Approach:**

This project will compare the performance of neural network classifiers, including neurobiologically based neural networks under development by ONR contractors, with well-documented classifiers using current pattern recognition techniques.

**Progress:**

This contract is new in FY89.

**TITLE:** Physiology, Anatomy, and Psychophysics of Parallel Processing in the Primate Visual Cortex.

**PRINCIPAL**

**INVESTIGATOR:** David H. Hubel  
Harvard College  
Department of Physiology  
(617) 732-1655

**R&T PROJECT CODE:** 442g003    **CONTRACT No:** N0001488K0200

**CURRENT END DATE:** 30 JUN 1991

**Objective:**

The first objective is to examine differences in responses between cortical layers in order to learn more about the transformation of information. The second objective is a detailed analysis of single cell properties in Visual Areas 1 and 2 as predicted from psychophysical experiments. The third objective is to continue studying the intrinsic connectivity among the three kinds of stripes in Visual Area 2. The fourth objective is to use voltage sensitive dyes to examine cortical column geometry in Visual Areas 1 and 2.

**Approach:**

To use anatomical tracer studies, physiological recordings, 2-deoxyglucose autoradiography and voltage-sensitive dyes to more clearly define which visual functions might be processed by each anatomically defined subsystem and to use psychophysical studies to explore how human visual perception correlates with the segregation and parallel processing seen in the physiological and anatomical studies in other primates.

**Progress:**

Drs. Livingstone and Hubel have shown that (a) the segregation of visual functions demonstrated by anatomical-physiological studies of monkey V2 visual cortex successfully predicted human psychophysical capabilities, (b) the magno- and parvocellular divisions of lateral geniculate nucleus, which mediate different visual abilities, exhibit the same retinal innervation density as a function of retinal eccentricity, and (c) that the color, contrast, and temporal properties of geniculate neurons correlate with human perceptual results.

**Report:**

Livingstone, M., & Hubel, D. (1988). Segregation of form, color, movement, and depth: Anatomy, physiology, and perception. Science, 240, 740-749.  
Livingstone, M. & Hubel, D. (1988). Do the relative mapping densities of the magno- and parvocellular systems vary with eccentricity? Journal of Neuroscience, 8, 4334-4339.



**TITLE:** Cerebellar Multi-Sensory Nonlinear Control

**PRINCIPAL**

**INVESTIGATOR:** James D. Keeler  
Microelectronics & Computer Technology Corp.  
(213) 394-8599

**R&T PROJECT CODE:** a44e003    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objectives of this research are (1) to characterize the capabilities and limitations of sparse distributed memories for prediction applications, (2) to overcome the control problems produced by a large number of degrees of freedom by using an improved architecture (similar to the cerebellum), (3) to design a scalable, modular neural network algorithm, (4) to design a neural network for multi-sensory fusion and nonlinear control problems, (5) to demonstrate the utility of this algorithm on forecasting and process control applications, and (6) to design a skeleton hardware architecture.

**Approach:**

The two main tasks are (1) design and testing of adaptive (feedforward) neural nets for prediction and forecasting of multi-sensory data, (2) incorporation of these predictive, adaptive nets into a hierarchical feedback network for nonlinear control problems. The PI will build on the mathematical foundations laid out by Marr-Albus and Kanerva in their Sparse Distributed Memory models. These memory models are very similar to the cerebellum in their structure, and the PI will use existing knowledge of cerebellar physiology as an inspiration of how to extend the SDM concept and to build a better architecture and algorithm for multi-sensory process control applications. Other features of this approach include: investigation of codon representation in a three-layer network, the relation of internal representation to prediction of future dynamics, the use of analytical and numerical tools from nonlinear system dynamics to view internal representations as reconstructed chaotic attractors, and testing the overall system with real data from challenging industrial process control applications.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Real-Time Neural Network Tracking Models Based on  
Biological Eye-Tracking Mechanisms

**PRINCIPAL**

**INVESTIGATOR:** Stephen G. Lisberger  
University of California  
Department of Physiology  
(415) 476-1062

**R&T PROJECT CODE:** a44f007    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this research is to develop and characterize a distributed, neural network model of tracking control based on the control strategies used by the eye tracking system.

**Approach:**

The PI will use features of sensorimotor processing in the eye tracking system of primates as a starting point for explorations of how tracking might be accomplished by machines. He will develop a neural network model that uses the basic control strategies of the brain. The model will use a new back propagation algorithm that (1) has dynamics, (2) operates on time-varying inputs such as those that confront real-time tracking systems, and (3) includes recurrent connections among units. The model will employ both hardwired negative feedback, so that it can modify its behavior in response to the consequences to initial actions, and long-term changes in the weights of connections between units, to customize initial responses. He will use the model to investigate how a tracking task is represented within a distributed network, and to study the contributions to good tracking performance of each of the brains control strategies.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Biologically Based Neural Networks for Active  
Perceptual Processing

**PRINCIPAL**

**INVESTIGATOR:** Gary Lynch  
University of California, Irvine  
Department of Psychobiology  
(714) 856-4274

**R&T PROJECT CODE:** a44e007    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 SEP 1991

**Objective:**

The primary objective is an investigation of neural network interactions arising from a model of the olfactory bulb. These interactions will be based on "real" biological rules including dendritic structure, neurochemical events and spatiotemporal patterns of physiological synaptic changes. The objectives include a feasibility study of the electronic implementation of these biological processes in VLSI devices.

**Approach:**

Computer simulations at the level of single neurons and nets will be conducted to examine the information processing in distinct brain structures. This approach includes a theoretical analysis of the properties of individual networks, their hierarchical interactions, and comparison with the computational properties of existing artificial neural networks.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Modelling Temporal Dynamics in the Classification of Auditory Signals

**PRINCIPAL**

**INVESTIGATOR:** Daniel Margoliash  
The University of Chicago  
Anatomy Department  
(312) 702-8090

**R&T PROJECT CODE:** 4426501      **CONTRACT No:** N0001489J1509

**CURRENT END DATE:** 31 JAN 1992

**Objective:**

The objective of this research is the elucidation of the neural mechanisms and algorithms used by animals to process auditory signals in order to provide critical insights for automating the classification of acoustic signals.

**Approach:**

The PI proposes to model both the recognition and production of song in oscine passerines (songbirds) and to test and modify these models in conjunction with ongoing neurophysiological and behavioral experiments. This is a well documented system for studying adaptive classification, and the PI has discovered forebrain areas with neurons which selectively respond to specific learned calls.

**Progress:**

This effort has two performance sites: (1) At U. Chicago, a backpropagation algorithm has been implemented and tested with complex acoustic inputs. Scaling of the net for very large problems has been undertaken. An architecture has been identified which limits the connectivity of hidden nodes while constraining the output nodes to look backwards in time. Hence the neurons output can be viewed as a sequential activation pattern of a series of output nodes that therefore preserve the temporal dynamics of neuronal responses. (2) At RAND Corp., construction of models of the response properties of neurons in HVC has been undertaken, and dynamical models are being explored which integrate temporal information in the recognition machinery rather than through conversion to a pseudo-visual recognition problem using delay lines. Neurons which show highly selective responses to particular bird calls are being modelled.

**TITLE:** Laboratory for Silicon Neural Systems

**PRINCIPAL**

**INVESTIGATOR:** Carver A. Mead  
California Institute of Technology  
Department of Computer Science  
(818) 356-6841

**R&T PROJECT CODE:** 414p006     **CONTRACT No:** N0001489J1675

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

The objective is to develop a deeper understanding of the collective computational capability of neural systems and to use silicon fabrication technology to implement these neural systems on silicon.

**Approach:**

The approach is to investigate the way the sensory systems process information, including the visual system, the auditory system, and sensory motor system. Analog silicon systems that learn will be investigated using electrically-erasable floating-gate memory technology. Silicon chips for visual tracking, visual focusing, binocular stereopsis, VOR, inner plexiform, neural integration, central pattern generation, and auditory classification will be designed and fabricated during this research program.

**Progress:**

Various silicon chips based on known neural architectures and understood neural systems have been designed and fabricated. An adaptive silicon retina has been made that can adapt to various visual conditions, very much like the real human retina. The chip is based on 2 micron CMOS technology using the parasitic bipolar transistor as photo-sensor and using polysilicon floating gate as analog charge storage device. A spatial sound localization chip has also been made based on the understanding of the Barn Owl's auditory system. Chips that can generate rhythmic activity such as the central pattern generator in the marine mollusc Tritonia have been designed and fabricated. Silicon circuits for winner-take-all, which is very common in models for neural computation, have been designed and demonstrated.

**Report:**

Mead, C. (1989). Analog VLSI and neural systems. Addison-Wesley Publishing Co., New York.

**Outside Funding:**

This work is currently supported in cooperation with the Electronics Division (Code 1114SE).

**TITLE:** Neural Networks: Comparative Performance Measurements

**PRINCIPAL**

**INVESTIGATOR:** David J. Montana  
BBN Laboratories Incorporated  
(617) 873-3000

**R&T PROJECT CODE:** a44d004    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective is the comparative performance of two types of neural networks which have been iteratively tuned, and optimized, upon sonar signal classification.

**Approach:**

The contractors will implement backpropagation and genetic algorithm neural networks. The comparative performance of these nets applied to sonar acoustic transient classification will be examined for cases in which components of the networks are varied. These components include (a) node transfer functions, (b) optimization criterion, and (c) training procedures. The neural networks will operate directly from spectrally transformed data. The neural networks will be iteratively tuned for classification of acoustic transients. The performance of the nets will be compared with that of traditional sonar techniques and trained human operators.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE: Neural Network Feature Extraction and Classification  
for Sonar Signals**

**PRINCIPAL**

**INVESTIGATOR:** Asa R. Simmons  
Raytheon Company  
(401) 847-8000

**R&T PROJECT CODE:** a44c001    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective is to develop and evaluate hybrid nets using Nestor RCE net modules which make optimum use of the features present in a set of acoustic transients, and to produce benchmarks of the performance of these nets, including cases in which modules use backpropagation algorithms instead of RCE algorithms.

**Approach:**

The approach includes preprocessing via Fourier transform of segmented raw acoustic signal to produce a spectrogram that will be encoded by a series of overlapping windows in frequency and time domains. The windows on the spectrogram slide along the time domain as the signal evolves. The network architecture consists of (1) a hybrid subsystem consisting of a heuristic feature extractor, feature extraction net (RCE), RCE classifier, and control loops from classifier back to feature extraction, and (2) an all neural net subsystem with an adaptive (unsupervised learning) feature extractor net, followed by an RCE classifier. The output of both the systems 1 and 2 will be combined at a controller stage to determine the classification of acoustic transients.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Comparative Performance Measurements of Neural  
Network Nearest Matched Filters for Sonar Signal  
Classification

**PRINCIPAL**

**INVESTIGATOR:** Patrick K. Simpson  
General Dynamics Corporation  
Electronics Division  
(619) 573-2417

**R&T PROJECT CODE:** a44d003    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective is to provide quantitative measures of the sonar signal classification performance of three different neural networks designed for spectro-temporal processing, and an evaluation of several alternative pre-processing techniques.

**Approach:**

Sonar signal classification performance will be evaluated for (a) the GDE1 fuzzy post-processed nearest matched filter neural net (an extension of Grossberg's avalanche net, and Hecht-Nielsens nearest matched filter), (b) the Viterbi net nearest matched filter (based on Gaussian classifiers and Hidden Markov Models), and (c) GDE2 on-line learning spatiotemporal pattern classifier (constructed from Kohonen's Learning Vector Quantization, and Grossberg's matched filters, temporal decay spatial activation nets, and adaptive resonance theory). Several alternative techniques for preprocessing the sonar transients into a suitable spectral estimation for the neural networks. These are: (1) fast Fourier transforms, (2) higher order zero crossings, and (3) adaptive noise cancellation by LMS or backpropagation. Performance measurements will be collected for each of the three nets, including false alarm rate. Development and operation time analysis will be performed for these applications.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.



**TITLE:** Comparative Sonar Signal Discrimination Performance  
Using Neural Network Techniques

**PRINCIPAL**

**INVESTIGATOR:** James C. Solinsky  
Science Applications International Corp.  
Advanced Systems Division  
(619) 546-6007

**R&T PROJECT CODE:** a44b001    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The PI proposes to develop a hybrid approach to sonar acoustic transient classification. This involves (a) identifying the best transient screening and feature detection processors, and (b) the development of self-learning artificial neural network algorithms.

**Approach:**

The sonar data will consist of "biologics" and data provided by DARPA. The equipment includes SAIC's commercially available neural network simulator. The features extracted from acoustic transients are encoded in a feature vector in classification space. The SAIC neural net classifier can feed back to the event feature extractor to regulate the density of feature vectors or prune out feature value axes which are irrelevant. A subsequent stage of the neural net determines the clustering of temporal patterns. The neural net algorithm to be examined shares some properties with the adaptive resonance theory (ART) of Grossberg.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Control of Biosonar Behavior by the Auditory Cortex

**PRINCIPAL**

**INVESTIGATOR:** Nobuo Suga  
Washington University  
Biology Department  
(313) 889-6805

**R&T PROJECT CODE:** 4426812    **CONTRACT No:** N0001489RM24002

**CURRENT END DATE:** 31 DEC 1989

**Objective:**

The objectives are (1) to use lesion techniques to validate physiological analyses of the neural substrate of bat biosonar capabilities, and (2) to identify the neural substrate of bat hyperacuity.

**Approach:**

Bats will be trained to carry out a variety of echolocation tasks, and then will be subjected systematically to lesions in physiologically identified brain regions believed responsible for various aspects of echolocation behavior. The effects of the lesions on performance will be studied.

**Progress:**

Normal bats tracking a target compensate for the doppler shift produced by their movement. They can compensate for 80% of the doppler shift with a reaction time of 96 ms. Following bilateral auditory cortical ablation the amount of doppler compensation was reduced to 35%, with RT of 150 ms. Hence, the behavioral compensation involves subcortical control.

**Report:**

Suga, N. (1988). What does single-unit analysis in the auditory cortex tell us about information processing in the auditory cortex? In P. Rakic & W. Singer (Eds.), Neurobiology of neocortex. Wiley & Sons.

Gaioni, S. J., Suga, N., & Riquimaroux, H. Effects of bilateral ablations of the auditory and/or cingulate cortices on the biosonar behavior of the mustached bat (*Pteronotus parnelli*). Presented at Soc. Neurosci. 1988, in prep. J. Neurophysiol.

**Outside Funding:**

Partial funding provided by AFOSR.

**TITLE:** Detection of Acoustic Motion by Passive Listening

**PRINCIPAL**

**INVESTIGATOR:** Terry T. Takahashi  
University of Oregon  
Department of Biology  
(503) 686-4544

**R&T PROJECT CODE:** 4426500    **CONTRACT No:** N0001489J1582

**CURRENT END DATE:** 31 MAY 1992

**Objective:**

The objective is to derive baseline data regarding the sensitivity of neurons in the owl's auditory system to moving acoustic targets in the dark, so that the capabilities of the neuronal circuits may be modelled and simulated. By studying acoustic motion-detection, the PI will address the general issue of how incoming information is stored, and how that stored information influences the perception of future signals.

**Approach:**

The approach utilized in this research for the design and improvement of passive, acoustic, motion-detecting and target-tracking devices is to study a biological system that is specialized for non-visual predation. The barn owl is known to capture moving prey, in absolute darkness, using only its sense of hearing. The PI has proposed a systematic, neurophysiological analysis of acoustic motion-sensitivity in the auditory system.

**Progress:**

This contract is new in FY89.

**TITLE:** Neural Networks Sonar Signal Discrimination

**PRINCIPAL**

**INVESTIGATOR:** Charles S. Weaver  
Maxim Technologies, Inc.  
(408) 748-1130

**R&T PROJECT CODE:** a44d002    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this research is the investigation of two different neural networks (time delay neural network, and adaptive trees) applied to sonar signal recognition, and a preliminary study of the VLSI architectures for implementing these nets.

**Approach:**

Programs to generate pattern vector sets from acoustic data will be written to provide inputs to the neural nets. A time delay neural net that does segmentation internally will be developed and trained using threshold logic units and a modified back propagation training algorithm. The decision surfaces implemented by the nets will be investigated to determine how the networks separate sounds outside the training set. A network that uses binary decision trees and binary pattern vectors will be tested. There will be a limited study of network architecture to estimate hardware complexity, size, power consumption, and relative cost.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Adaptive Information Processing in Auditory Cortex

**PRINCIPAL**

**INVESTIGATOR:** Norman M. Weinberger  
University of California, Irvine  
Center for Neurobiology of Learning and Memory  
(714) 856-5512

**R&T PROJECT CODE:** 4426805      **CONTRACT No:** N0001487K0433

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

The PI will test working hypotheses regarding putative principles of adaptive information processing in sensory cortex by obtaining neurophysiological data simultaneously from more than one neuron via an on-line objective waveform-sorting algorithm.

**Approach:**

The frequency tuning of single neurons will be determined immediately before and after various stages of training in classical conditioning paradigms using pure tone as the conditioned stimulus and rewarding stimulation of the hypothalamus as the unconditioned stimulus. Independent behavioral indices of learning will be obtained by quantification of the pupillary dilation conditioned response.

**Progress:**

This group has discovered that neuronal receptive fields in auditory cortex are shifted toward the frequency of the signal tone during rapid behavioral associative learning. This adaptive information processing indicates that sensory cortical organization is dynamic. They have formulated and are initiating tests of a "triplex" model of adaptive information processing in which the outputs of the three types of sub-cortical information systems (auditory lemniscal, non-lemniscal, and N. basalis) are integrated in neocortex to produce selective modification of receptive fields.

**Report:**

Weinberger, N. M., & Diamond, D. M. (1987). Physiological plasticity in auditory cortex: Rapid induction by learning. Prog. Neurobiol. 29:1-55.

Weinberger, N. M., Ashe, J. H., Metherate, R., McKenna, T. M., Diamond, D. M., Bakin, J. S., & Cassady, J. M. (1989). Neural adaptive information processing: a preliminary model of receptive field plasticity in auditory cortex during Pavlovian conditioning. In J. Moore and M. Gabriel (Eds.), Neurocomputation and learning: foundations of adaptive networks. Bradford Books, MIT Press.

**TITLE:** Modeling of Learning Induced Receptive Field  
Plasticity in Auditory Neocortex

**PRINCIPAL**

**INVESTIGATOR:** Norman Weinberger  
University of California, Irvine  
Department of Psychobiology  
(714) 856-5512

**R&T PROJECT CODE:** a44e004    **CONTRACT No:** Not available

**CURRENT END DATE:** 31 JUL 1991

**Objective:**

The objective of this research is to develop a mathematical model of adaptive information processing the brain. In particular a mathematical model of the mechanisms by which neurons in the auditory cortex are modified during learning will be developed using approaches derived from machine learning.

**Approach:**

The investigators will employ a gradient descent approach based on a window training procedure. This procedure has been successfully characterized in trainable machines. Data previously obtained from neurophysiological studies will be used to test and refine the model. The model will predict specific learning trajectories for different "behavioral" paradigms (eg. discrimination, extinction). The model also will predict the mechanisms of modifications of frequency response observed in neurons of the auditory cortex. The approach of combining adaptive processes from neurobiology with proven technologies based on mathematical machine learning will permit deriving principles applicable to the design and technological implementation of adaptive information processing machines.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Hybrid Classifier for Sonar Transient Signals

**PRINCIPAL**

**INVESTIGATOR:** James W. Whiteley  
Tracor Applied Sciences, Inc.  
(512) 926-2800

**R&T PROJECT CODE:** a44d001    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The goal of this research is to identify and evaluate artificial neural network architectures that are optimal for the adaptive classification of acoustic transients.

**Approach:**

The approach is to develop a hybrid classifier that integrates the best attributes of neural networks and conventional classifiers for sonar signal classification. Innovative aspects of the approach are: (1) establishment of a parametrized set of optimal features by investigation of the application of higher order spectra and image processing methods to sonar signal feature extraction; (2) the development of a time delay neural network that is matched to time varying features of transients; (3) the use of internal representations and projective fields of neural networks to identify novel discriminators; (4) the use of pre-encoded information from conventional classifiers to speed neural network training; and (5) the synergistic interaction between neural networks, feature extractors, and conventional classifiers to iteratively drive toward an optimal classifier design.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**BIOLOGICAL INTELLIGENCE**

**LOCAL NEURAL CIRCUIT  
INTERACTIONS**

*193/194*



**TITLE:** Neuronal Micronets as Nodal Elements

**PRINCIPAL**

**INVESTIGATOR:** Thomas H. Brown  
Yale University  
Department of Psychology  
(203) 432-7009

**R&T PROJECT CODE:** a44e005    **CONTRACT No:** Not available

**CURRENT END DATE:** Not available

**Objective:**

The objective of this research is to develop micronets based on the electrotonic structure and non-linear dynamics of real neurons, build architectures based on ensembles of these micronets, and to evaluate the computational performance of these nets on pattern recognition tasks.

**Approach:**

The researchers will first develop micronets which capture particular aspects of neurons. The micronets will be sparsely connected, higher-order nets. Trade-offs among number of processors, number of connections, and number of layers within the micronets will be examined. Several variants of Hebbian modification algorithms will be explored. Architectures composed of micronets will be developed. These will consist of an input buffer layer fully connected to a second layer containing micronets sparsely connected with each other by Hebbian synapses. The training sets consist of a large collection of patterns with a high degree of internal structure. The performance of this architecture will be compared with a conventional architecture with the second layer containing randomly connected PEs. Performance measures will be (1) learning ability (number of patterns, ability to generalize, discrimination of similar patterns), (2) scaling properties (consequence of increased dimensionality of input data, increased number micronets, or PEs per micronet), and (3) ease of VLSI implementation.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

Funds for this project were provided by DARPA.

**TITLE:** Neural Circuitry of Behavior as a Substrate for  
Information Processing: A Developmental Analysis in  
Aplysia

**PRINCIPAL**

**INVESTIGATOR:** Thomas J. Carew  
Yale University  
Department of Psychology  
(203) 432-4675

**R&T PROJECT CODE:** 4426806      **CONTRACT No:** N0001487K0381

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

Three specific questions will be addressed, each at a BEHAVIORAL and a CELLULAR level of analysis: 1) How are neural networks for specific behavioral responses assembled and activated during development? 2) How are independent networks interconnected during development to produce integrated complex behavioral sequences? 3) How are these integrated networks modulated by experience and learning?

**Approach:**

The marine mollusc *Aplysia californica* has proven to be an extremely useful preparation for the analysis of the role of identified neurons and neural circuits in behavior and learning. The primary goal of this research is to use development in *Aplysia* as an analytic tool to examine the way specific neural circuits acquire the capacity for information processing. A broad range of different defensive behaviors will be examined to permit establishing principles of neuronal organization unique to particular types of response systems on the one hand, and to principles of general significance on the other. These behaviors will include: 1) graded reflexes (the gill withdrawal reflex and the tail withdrawal reflex); 2) an all-or-none response (the inking response); and 3) a cyclical behavior (escape locomotion).

**Progress:**

The PI has shown that a reflex and fixed action pattern, which utilizes a common set of effector organs, emerges according to different developmental timetables. The PI is now testing specific hypotheses concerning the developmental assembly of these behaviors on a cellular level.

**Report:**

Carew, T. J. (1989). Developmental assembly of multiple components of learning and memory in *Aplysia*. In J. H. Byrne & W. Beng (Eds.), Neural models of plasticity: Theoretical and empirical approaches. Academic Press.  
Cash, D., & Carew, T. J. (1989). Quantitative analysis of the development of the CNS in juvenile *Aplysia*. J. Neurobiology, 20, 25-47.

**TITLE:** Synapse-Specific Facilitation During Learning and Memory

**PRINCIPAL**

**INVESTIGATOR:** Gregory A. Clark  
Princeton University  
Department of Psychology  
(609) 452-4483

**R&T PROJECT CODE:** 4426820    **CONTRACT No:** N0001489J1954

**CURRENT END DATE:** 30 NOV 1990

**Objective:**

To determine whether long-term as well as short-term facilitation can be synapse specific, and then to define the underlying cellular mechanism (e.g. is new protein synthesis required, are new proteins used selectively?). To investigate a possible physiological and behavioral role in synapse-specific facilitation, that is, as a neural mechanism for response specificity in classical conditioning of the siphon-withdrawal response in Aplysia.

**Approach:**

Despite substantial progress in the neurobiology of learning, a fundamental question still remains concerning the basic unit of information storage in the central nervous system. Does learning occur at the level of individual cells, or instead at the level of individual synapses? Stated, another way, must plasticity occur at all synapses of a given cell, so that it modifies transmission onto all postsynaptic targets? Or alternatively, is it possible to enhance transmission at one set of terminals, without enhancing transmission at other terminals of the same cell? Synapse-specific plasticity has been incorporated into a number of conceptual and computational models of learning in neural networks. This work will directly test whether branch-synaptic facilitation occurs and what the relevant parameters are.

**Progress:**

Experimental evidence suggests that short term facilitation of synapses of siphon sensory cells of Aplysia can be specific to selected synapses, without occurring at other synapses of the same cell.

**Report:**

Clark, G. A., & Hawkins, R. D. (1988). Learning and the single cell: Cellular strategies for information storage in the nervous system. In J. L. Davis, R. W. Newburgh, & E. Wegman (Eds.), Brain structure, learning, and memory. Washington, D.C.: American Association for the Advancement of Science.

Frost, W. N., Clark, G. A., & Kandel, E. R. (1988). Parallel processing of short-term memory for sensitization in Aplysia. J. Neurobiol., 19, 297-334.

**TITLE:** 1989 Gordon Research Conference on Neural Plasticity,  
July 17-21, 1989

**PRINCIPAL**

**INVESTIGATOR:** Alexander M. Cruickshank  
Gordon Research Conference  
(401) 783-4011

**R&T PROJECT CODE:** 4426150    **CONTRACT No:** N0001489J1291

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

Understanding of the mechanisms underlying learning and memory requires comprehension of the biochemical, cellular, and neural systems substrates. This information may provide suggestions for improving learning processes, assessing the impact of pharmacological agents on learning, and the possibility of alternate hardware architectures.

**Approach:**

The PI is the Director of the Gordon Research Conferences. This organization has planned this meeting to consist of 40 state of the art talks, a keynote address, and a poster session.

**Progress:**

This contract is new in FY89.

**TITLE:** Neural Network Models of Primate Motor System

**PRINCIPAL**

**INVESTIGATOR:** Eberhard E. Fetz  
University of Washington  
Department of Physiology and Biophysics  
(206) 543-4839

**R&T PROJECT CODE:** 4426300    **CONTRACT No:** N0001489J1240

**CURRENT END DATE:** 30 NOV 1990

**Objective:**

The PI will develop two types of models: on the cellular level he will model the synaptic interactions between neurons, and on the system level he will develop network simulations of the primate motor system. The objective of these models will be to provide a quantitative "real time" model of primate motor activity.

**Approach:**

The following experimental data will be included in a neural network model of the primate motor system: the activity of supraspinal premotor cells and their target forelimb muscles; the connections of these cells to their target motoneurons; and quantitative measures of the strength of synaptic interactions between neurons. These data were previously obtained in the laboratory of the PI.

**Progress:**

This contract is new in FY89.

**TITLE:** Interneuronal Information Processing

**PRINCIPAL**

**INVESTIGATOR:** Daniel Gardner  
Cornell University Medical College  
Department of Physiology  
(212) 472-6669

**R&T PROJECT CODE:** 4426021    **CONTRACT No:** N0001486K0491

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

Project will identify and characterize types of functional elements available to an actual neural network, the ways in which they are combined, and the functional consequences of their use. The goal is both a generalizable biophysical description of synapses and an understanding of the role of the synapses in the adaptive behavior of a cell and network.

**Approach:**

The PI will develop mathematical models of the stochastic processes involved in heterosynaptic plasticity. The PI will test these models experimentally with intracellular recording, under voltage clamp conditions in buccal ganglia of aplysia.

**Progress:**

The PI has developed a hypothesis regarding the biophysical factors involved in heterosynaptic synaptic plasticity in neural networks. This postulates that the variance in the fluctuations of membrane potential, rather than depolarization per se, enables synaptic plasticity. In the first experimental tests of this hypothesis, conducted in Aplysia buccal ganglia, it was found that noise injected into voltage-clamped postsynaptic neurons failed to produce either nonspecific or associative effects on synaptic efficacy. The PI proposes that the time integral of postsynaptic conductance, rather than postsynaptic potential amplitude be used as the biological measure of synaptic weight.

**Report:**

Gardner, D. (1988). A test for modulation of synaptic efficacy by induced membrane potential variance. Brain Research Bulletin, 21, in press.

Gardner, D. (1989). Noise modulation of synaptic weights in a biological neural network. Neural Networks 2, in press.

**TITLE:** Synaptic Structural Effects of Long-Term Potentiation  
in the Hippocampal Formation

**PRINCIPAL**

**INVESTIGATOR:** William T. Greenough  
University of Illinois  
Department of Psychology  
(217) 333-4472

**R&T PROJECT CODE:** 4426640     **CONTRACT No:** N0001489J1556

**CURRENT END DATE:** 31 JAN 1992

**Objective:**

Long term potentiation (LTP) is a long lasting increase in the responsiveness of neurons brought about by high-frequency activation of their input fibers. A similar phenomenon occurs in response to behavioral learning or exploratory activity. Understanding how the brain alters its cells to encode memory will be of value for attempting to devise learning systems involving neurally-inspired architecture.

**Approach:**

The work requires the use of a number of anatomical, biochemical, and neurophysiological techniques. Many of these techniques are implemented by studying hippocampal tissue wherein chemical and anatomic qualities have been changed as a function of "experience". These changes can either be induced in vitro or in vivo, and the tissue can be removed and kept alive for long periods under appropriate conditions.

**Progress:**

Major recent findings are: (1) As reported previously with LTP, shaft and sessile spine synapses form in association with kindling in hippocampal subfield CA1 in vitro. This suggests a common mechanism for LTP and K, as well as a possible mechanism of induction of epilepsy. (2) The induction of both LTP and K is accompanied by changes in the characteristics of astrocytes. (3) A development in the lab which will enable us to further pursue these issues is the upright dentate slice. In contrast to conventional dentate gyrus slices, the upright slice contains complete inhibitory circuitry and exhibits robust LTP (in 71% of cases). (4) Behavioral LTP in the hippocampal formation shows an algebraically additive relationship with electrically induced LTP.

**Report:**

Greenough, W. T., & Bailey, C. H. (1988). The anatomy of memory: Convergence of results across a diversity of tests. Trends in Neurosci. 11, 142-147.

Greenough, W. T. (1989). Mechanisms of behaviorally-elicited and electrically elicited long-term potentiation. Int. J. Neurol., in press.

**TITLE:** Neural Mechanisms of Preparatory Processes in  
Stimulus-Response Associations and Movement  
Programming

**PRINCIPAL**

**INVESTIGATOR:** Sylvan Kornblum  
Regents of the University of Michigan  
Department of Psychology  
(313) 763-1101

**R&T PROJECT CODE:** 4426310    **CONTRACT No:** N0001489J1557

**CURRENT END DATE:** 31 JAN 1992

**Objective:**

The objective is to provide a systematic account of the excitatory and inhibitory patterns of activity that occur in the sensory-motor transfer structures of the brain.

**Approach:**

Two series of experiments are planned. The first addresses the question of identifying and characterizing neural associative structures underlying the preparation of whole movements. During the behavioral stimulus-response compatibility paradigm, human cortical activity patterns will be monitored with PET scans, and monkeys cortex will be recorded electrophysiologically. The second addresses the question of neural structures involved in coding movement features in simple voluntary movement. During performance of the movement priming paradigm, single unit recordings will be obtained from motor, premotor, and parietal cortices. Sites: human work-Univ. Mich., monkey work-Canada and France.

**Progress:**

This contract is new in FY89.



**TITLE:** Characterization of Ground Squirrel Retina Ganglion Cells

**PRINCIPAL**

**INVESTIGATOR:** Nidza Lugo-Garcia  
University of Puerto Rico  
Medical Sciences Campus  
(809) 721-4149

**R&T PROJECT CODE:** 4426205    **CONTRACT No:** Not available

**CURRENT END DATE:** 30 JUN 1993

**Objective:**

Determine the retinal projection pathways in the central nervous system responsible for color vision. Such information may permit precise identification of the locus of visual system disorders.

**Approach:**

Conduct a series of experiments to (1) characterize the dendritic arborization of cells projecting to different central nervous system areas, and (2) determine if retinal ganglion cells project to more than a single target area.

**Progress:**

This contract is new in FY89.

**TITLE:** Experimental Data Base Generation for Computational Modelling

**PRINCIPAL**

**INVESTIGATOR:** Allen I. Selverston  
University of California, San Diego  
Neuroscience Department  
(619) 534-2672

**R&T PROJECT CODE:** 4426128      **CONTRACT No:** N0001488K0328

**CURRENT END DATE:** 31 MAY 1991

**Objective:**

The goals of the proposed research are to obtain physiological data from an invertebrate nervous systems which can be used to support the development of new computational models of neural functioning. These can serve as the basis for pattern recognition and motor control algorithms. Data will be obtained relating the various conductances present in single neurons to their individual information handling capabilities. Additional information will be obtained on synaptic and network properties which could be used in modelling the system. As data is obtained, it will be incorporated into new computational models which will then be tested with experimental preparations.

**Approach:**

The model consists of only thirty neurons yet generates two complex output patterns. Moreover, these neurons are individually identifiable and their pattern of synaptic connectivity is stereotyped and well characterized. It is easy to record intracellular potentials in these neurons, including synaptic potentials. The behavior of the entire system can be altered by injecting current into single cells or by the application of various neuromodulators which alter synaptic strengths. This model system is perhaps the best understood pattern generator, and is well suited to a quantitative analysis.

**Progress:**

The PI has shown: (a) a CCK-like peptide is present in the stomatogastric system and can be released into the neuropil of the ganglion by stimulating the sole input nerve, and (b) a modified Hopfield network can successfully simulate three of the key cells in the pyloric circuit.

**Report:**

Turrigiano, G., & Selverston, A. I. (1989). Cholecystokinin-like peptide is a modulator of a crustacean central pattern generator. J. Neurosciences, 9:2486-2501.  
Selverston, A. I. (1988). A consideration of invertebrate central pattern generators as computational data bases. J. Neural Networks, 1:109-117.

**TITLE:** Dendritic Properties and Neural Networks.

**PRINCIPAL**

**INVESTIGATOR:** Gordon Shepherd  
Yale University  
School of Medicine  
(203) 785-4336

**R&T PROJECT CODE:** 442h001     **CONTRACT No:** N0001489J1603

**CURRENT END DATE:** 31 DEC 1991

**Objective:**

The objectives are to identify the essential features of cortical dendrites and microcircuits and to incorporate them into more realistic models of cortical function.

**Approach:**

Using compartmental modelling techniques, the PI will pursue analysis of logic operations inherent in intradendritic communication signals. He will develop a basic cortical circuit in parallel with experimental studies in cortical slices obtained as routine biopsies in neurosurgical operations. Since the cortex and thalamus form a functional unit, he will develop a computational model for the thalamus, and integrate this with the cortical basic circuit.

**Progress:**

The PI has developed a new circuit analysis program (SABER) that enables neural models to be constructed with much greater ease and flexibility. He has also compared logic operations arising from active dendritic spine interactions with those arising from active sites in dendritic branches and branch points.

**Report:**

Shepherd, G. M., & Greer, C. A. (1988). The dendritic spine: Adaptations of structure and function for different types of synaptic integration. In R. Lussek (Ed.), Intrinsic determinants of neuronal form. A. R. Liss Press.

**TITLE:** Computer Simulation of Neural Systems

**PRINCIPAL**

**INVESTIGATOR:** Thomas P. Vogl  
Environmental Research Institute of Michigan  
(703) 520-5250

**R&T PROJECT CODE:** 4426132    **CONTRACT No:** N0001488K0659

**CURRENT END DATE:** 31 JUL 1991

**Objective:**

The technical objectives involve finding the answers to the following questions related to Dr. Alkon's model: (1) What are the roles of presynaptic, postsynaptic, and intraneural time delays in biological network performance and stability? (2) Which features of the biologic system are essential for the memory/recognition process and which are phylogenetic detritus? (3) What are the qualitative and quantitative differences between long- and short-term memory? (4) What is the role of changes in the membrane potential curves (membrane polarization) in the learning process?

**Approach:**

Initially, efforts will focus on modelling the structure, neurochemistry, neurophysiology, and biophysics of the marine mollusc *Hermisenda crassicornis* with eventual extension to more complex, vertebrate systems. An essential feature of the proposed effort will be the close collaboration among neurophysiology and biophysics researchers at the National Institutes of Health (DHHS/NIH/NINCDS) and computer science and applied mathematics researchers at ERIM in all stages of the planning and execution of the research.

**Progress:**

The PI has developed (a) a lumped parameter model of *Hermisenda* which exhibits learning, retention, accelerated relearning, and output signals which have been confirmed in the biological preparation, and (b) a model based on invertebrate and vertebrate neural architectures called DYNamically STable Associative Learning (DYSTAL) which has demonstrated the abilities of signal classification and association.

**Report:**

Vogl, T. P., Alkon, D. L., & Blackwell, K. T. Dynamically stable associative learning (DYSTAL): A biologically motivated artificial neural network. Submitted to IJCNN 89 Conf., Wash., DC.

Alkon, D. L., Vogl, T. P., et al. Pattern recognition by an artificial network derived from biologic neural systems. Biol. Cybernet., in preparation.

Zink, W. T., Vogl, T. P., & Mangis, J. K. A neural network that classifies noisy patterns: An experimental comparison with statistical classifiers. Neural Networks, submitted.

# **BIOLOGICAL INTELLIGENCE**

## **MARINE MAMMALS**

207/208

**TITLE:** Nutritional and Thermal Requirements of Marine Mammals

**PRINCIPAL**

**INVESTIGATOR:** Daniel P. Costa  
University of California, Santa Cruz  
Institute of Marine Sciences  
(408) 429-2786

**R&T PROJECT CODE:** 4426702    **CONTRACT No:** N0001487K0178

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

This work unit addresses the maintenance requirements of captive dolphins and sea lions to establish criteria to assess nutritional status which in turn directly relates to animal health, an area of significant concern to Navy use of the animals.

**Approach:**

Perform a series of experiments to quantify maintenance requirements of bottlenose dolphins and californian sea lions and establish criteria to assess nutritional status, establish thermoneutral zones, and identify major routes of heat transfer.

**Progress:**

Bottlenose dolphins have a thermoneutral zone which has a lower limit of approximately 11-15 degrees C. and an undetermined upper limit which is greater than 28 C. Morphological factors account for the differences in the lower limit. Measures of oxygen consumption were lower than previously reported, ranging from 1.5 - 1.6 times that expected for a similar sized adult terrestrial mammal.

**Report:**

Castellini, M. A., & Castellini, J. M. (1989). Influence of hematocrit on whale blood glucose levels: new evidence from marine mammals. Am. J. Physiology, 256 (Regulatory Integrative Comp. Physiol. 25).

**TITLE:** Cell Mediated Immunologic Defense Mechanisms of Dolphins

**PRINCIPAL**

**INVESTIGATOR:** Bradley Fenwick  
Kansas State University  
Department of Pathology  
(913) 532-5634

**R&T PROJECT CODE:** 4426701    **CONTRACT No:** N0001487K0215

**CURRENT END DATE:** 31 AUG 1991

**Objective:**

Maintaining dolphin health is important to effective use of these animals in executing selected Navy tasks. This work unit will investigate the role of normal and disordered immunoregulation in disease resistance.

**Approach:**

Research will involve isolation, cloning and study of antigen specific T-lymphocytes from normal and immunized dolphins. Immune regulatory mechanisms will be studied by characterization of proliferative responses induced by various antigens in combination with interleukin-2 and primed macrophages.

**Progress:**

Improved methods for isolation, cryopreservation, and functional evaluation of dolphin lymphocytes were developed. The improved isolation procedure will permit application in field settings. The improved cryopreservation method allows lymphocytes to be transported for laboratory evaluation without significant loss of function, which also permits a series of retrospective samples to be evaluated simultaneously.

**Report:**

Fenwick, B. (1988). Stress as a factor in disease susceptibility. Proc. Inter. Assoc. of Aquatic Anim. Med.

**TITLE:** Dynamics and Diagnostic Value of Plasma Indicators of Stress in Small Cetaceans

**PRINCIPAL**

**INVESTIGATOR:** Joseph R. Geraci  
University of Guelph  
Department of Pathology  
(519) 823-8800

**R&T PROJECT CODE:** 4426706    **CONTRACT No:** N0001487J1114

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

Marine mammal health is a continuing concern to Navy research and operations. This work unit investigates the interaction of stress, iron metabolism, and the immune system so as to understand the underlying dynamics of disease resistance.

**Approach:**

Conduct experiments to establish dynamics and turnover of selected blood constituents in both healthy and diseased animals.

**Progress:**

In the past year efforts have focussed on identifying and isolating proteins responsible for thyroid hormone binding and transport in odontocete plasma using a comprehensive series of electrophoretic analyses. Cetaceans apparently lack pre-albumin one of the major classes of transport proteins found in humans. Search for a comparable protein continues; when found a specific assay for thyroid binding globulin (TBG) will be developed. TBG has been shown to have diagnostic and prognostic value in humans.

**Report:**

St. Aubin, D. J., & Geraci, J. R. (1989). Adaptive changes in hematologic and plasma chemical constituents in captive beluga whales. *Delphinapterus leucas*. Can. J. Fish. Aquat. Sci., 46, 1-8.



**TITLE:** Cognitive Processes and Characteristics of Bottlenose Dolphins

**PRINCIPAL**

**INVESTIGATOR:** Louis M. Herman  
University of Hawaii  
Kewalo Basin Marine Mammal Laboratory  
(808) 538-0067

**R&T PROJECT CODE:** 4426613      **CONTRACT No:** N0001485K0210

**CURRENT END DATE:** 30 SEP 1990

**Objective:**

The Navy uses marine mammals in a limited way. This work unit will explore the possibility of extending such use to more complex situations by means of acoustic and/or gestural signals.

**Approach:**

A series of experiments will be performed to determine (1) the ability of the dolphin to understand sentences expressed in artificial acoustic and/or gestural languages and (2) the possibility that the dolphin has the capability to produce and exchange information.

**Progress:**

Behavioral mimicry has been shown for the first time for both older and younger dolphins. After training to mimic behavior on familiar tasks, one dolphin was taught a new task. Later the second dolphin was directed to perform this new task by mimicking the response of the "model" dolphin. The second dolphin executed the desired response even though it had never been performed previously. Younger dolphins successfully mimicked behaviors performed by a human model.

**Report:**

Herman, L. M., Hovancik, J. R., Gory, J. D., Bradshaw, G. L., (1989). Generalization of visual matching by a bottlenosed dolphin (*Tursiops truncatus*) evidence for invariance of cognitive performance with visual or auditory materials. Journal of Experimental Psychology: Animal Behavior Processes, 15, 124-136.

**TITLE:** Mechanisms of Target Discrimination by Echolocating Dolphins

**PRINCIPAL**

**INVESTIGATOR:** Paul E. Nachtigall  
Naval Ocean Systems Center Detachment  
Research Branch  
(808) 257-5256

**R&T PROJECT CODE:** 4426709    **CONTRACT No:** N0001489WX24215

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

To increase our understanding of dolphin signal processing and explore the potential of resonance scattering theory for object identification and discrimination.

**Approach:**

Perform a series of experiments to determine the relationship between target resonance and dolphin discrimination capabilities, the importance of different parts of the resonance component; and the interaction between specular & resonance components of echoes.

**Progress:**

This contract is new in FY89.

**TITLE:** Representations in Dolphin Memory

**PRINCIPAL**

**INVESTIGATOR:** Paul E. Nachtigall  
Naval Ocean Systems Center Detachment  
Department of the Navy  
(808) 257-5256

**R&T PROJECT CODE:** 4426900    **CONTRACT No:** N0001489WX24016

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

This work unit addresses certain of the cognitive capabilities of the dolphin, with special emphasis on memory functions and representation of events in memory.

**Approach:**

Perform a series of experiments to investigate the dolphin's ability to represent sequences of events (a) in an unstructured list, and (b) in a serially structured sequence.

**Progress:**

An adult male dolphin was trained to perform three alternative delayed matching to sample tasks while wearing eyecups to occlude vision. Sample and comparison stimuli consisted of (a) a small and (b) a large PVC plastic tube, (c) a water filled stainless steel sphere, and (d) a solid aluminum cone. Stimuli were presented under water and the dolphin permitted to echolocate. Echolocation clicks to each sample and each comparison stimulus were recorded and analyzed. Choice accuracy averaged 95% correct. The dolphin apparently manipulated the number of clicks emitted to the various stimuli. A preliminary model for the dolphin's decision making processes was presented.

**TITLE:** Dolphin Cognition: Sensory Perception, Rhythmic Patterning, and Cross-Model Transfer in the Bottlenosed Dolphin

**PRINCIPAL**

**INVESTIGATOR:** Kenneth S. Norris  
University of California, Riverside  
Long Marine Laboratory  
(408) 429-2836

**R&T PROJECT CODE:** 4426704    **CONTRACT No:** N0001487K0192

**CURRENT END DATE:** 31 OCT 1989

**Objective:**

Assessment of the cognitive importance of patterning of dolphin acoustic signal streams may provide insight into vocal communication among dolphins and provide a basis for development of new or improved training procedures of use to navy programs.

**Approach:**

Experiments will investigate how and in what context dolphins rhythmically modulate their echolocation based message streams. This will include body scans, beam steering, and locomotion induced changes in the emitted signal stream.

**Progress:**

Initial data identified three rhythmic overlays on dolphin echolocation trains, a vertical oscillation associated with swimming movements, head scanning as the target is approached, and beam steering in which the acoustic stream appears to be shifted. Work is progressing on determining the function and importance of these overlays, and in the case of beam steering, possible mechanisms of generation.

**TITLE:** Animal Language Workshop

**PRINCIPAL**

**INVESTIGATOR:** Herbert L. Roitblat  
University of Hawaii  
Department of Psychology  
(808) 948-8027

**R&T PROJECT CODE:** 4426707    **CONTRACT No:** N0001489J1093

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

Understanding of possible animal communication systems and the possibility of language like learning, could lead to greatly improved training procedures to be used in Navy marine mammal projects.

**Approach:**

The conference is being organized by the principal investigator aided by an organizing committee. The meeting will be held in Honolulu, Hawaii, and will consist of daily sessions covering theoretical and experimental aspects of language learning in non-human primates and marine mammals, as well as psycholinguistics.

**Progress:**

This contract is new in FY89.

**TITLE:** Marine Mammal Cognitive Processes

**PRINCIPAL**

**INVESTIGATOR:** Ronald Schusterman  
University of California, Santa Cruz  
Long Marine Laboratory  
(408) 429-4945

**R&T PROJECT CODE:** 4426614      **CONTRACT No:** N0001485K0244

**CURRENT END DATE:** 30 SEP 1990

**Objective:**

The Navy uses marine mammals in a limited way. This work unit will explore the possibility of extending such use to more complex situations by means of acoustic and/or gestural signals.

**Approach:**

A series of experiments will be performed to determine the ability of the sea lion to understand sentences expressed in artificial acoustic and/or gestural language.

**Progress:**

Sea Lions were trained to report the presence or absence of objects in the pool, in response to gestural signs. The animals learned quickly and performed at a 90% level of accuracy over hundreds of trials. When given anomalous sign sequences, the animal would remain "on station" if the signs were out of order, or if the object sign or the action sign was omitted.

**Report:**

Schusterman, R. J., & Gisiner, R. (1988). Artificial language comprehension in dolphins and sea lions: The essential cognitive skills. The Psychological Record, 38, 311-348.

**TITLE:** Marine Mammal Health: The Interrelationship of  
Autochthonous Viruses and Stress

**PRINCIPAL**

**INVESTIGATOR:** Alvin W. Smith  
Oregon State University  
College of Veterinary Medicine  
(503) 754-2318

**R&T PROJECT CODE:** 4426703    **CONTRACT No:** N0001487K0164

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

To define more clearly the interrelationship of viral disease and stress and the decrement both impose on overall animal health, so as to improve the health and operational effectiveness of Navy marine mammal systems.

**Approach:**

Determine the stress status and viral profiles of healthy and sick marine mammals, focussing on developing assays for measuring the function of cellular immune component and changes therein resulting from stress or exposure to antigenic materials.

**Progress:**

Cetacean calicivirus, CCV-Tur-1, which causes vesicular lesions on dolphin bodies produces similar lesions in experimentally infected animals. Further the swine showed varying degrees of liver cell degeneration. This is the first time the finding that CCV-Tur-1 as well as other, but not all, caliciviruses can cause hepatitis has been reported.

**Report:**

Smith, A., Skilling, D., Benirschke, K., Albert, T., & Barlough, J. (1987). Serology and Virology of the Bowhead Whale, *Balaena mystecetus*. Jour. Wildlife Diseases.

**TITLE:** Investigation of Signature Whistles in Bottlenose Dolphin

**PRINCIPAL**

**INVESTIGATOR:** Peter L. Tyack  
Woods Hole Oceanographic Institution  
Department of Biology  
(617) 548-1400

**R&T PROJECT CODE:** 4426700    **CONTRACT No:** N0001487K0236

**CURRENT END DATE:** 31 JAN 1990

**Objective:**

Identification of the function of dolphin whistles and the ability of dolphins to mimic whistles may provide insight into vocal communication among dolphins and provide a basis for development of new or improved training procedures of potential use to Navy programs.

**Approach:**

Experiments will test the role of vocal learning and mimicry in the development of whistle repertoires in dolphins, and will try to determine the function of individually distinctive or mimicked whistles.

**Progress:**

Preliminary data suggest that the male dolphin calf develops a signature whistle very similar to that of the mother, while female calves develop whistles very distinct from the mother. As they develop, males tend to disperse more than females, broadening social relationships & expanding whistle repertoire. Such data suggest that males may be more readily adaptable to training involving whistle mimicry.

**Report:**

Watkins, W., Tyack, P., Moore, K., & Moore, J. (1987). The 20-Hz signals of finback whales (*Balaenoptera physalus*). J. Acoust. Soc. Am.



**TITLE:** 7th International Conference on Biomagnetism

**PRINCIPAL**

**INVESTIGATOR:** Samuel J. Williamson  
New York University  
Department of Physics  
(212) 998-7692

**R&T PROJECT CODE:** 4426708    **CONTRACT No:** N0001489J1776

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

To support a conference bringing together leading scientists working in the field of biomagnetism to discuss new findings and developments as they are relevant to sensing and recording of magnetic fields, with particular emphasis on neurally generated fields.

**Approach:**

Meetings will consist invited plenary talks, oral, and poster presentations covering theoretical and experimental aspects of biomagnetism, given by current researchers. A special tutorial session will be given to acquaint relative newcomers to the field.

**Progress:**

This contract is new in FY89.

**BIOLOGICAL INTELLIGENCE**

**BEHAVIORAL IMMUNOLOGY**

224/222

**TITLE:** Investigations of Stress Induced Alterations in  
Neutrophil Function

**PRINCIPAL**

**INVESTIGATOR:** Andrew S. Baum  
Uniformed Services Univ. of the Health Sciences  
F. Edward Hebert School of Medicine  
(301) 295-3270

**R&T PROJECT CODE:** 442d008    **CONTRACT No:** N0001489WM24001

**CURRENT END DATE:** 30 SEP 1989

**Objective:**

This project will measure individual differences in the psychological effects elicited by a physically and emotionally demanding field training experience, and study how these effects relate to changes in endocrine and immune system activity. The goal is to better understand the mechanisms determining who gets ill under adverse conditions.

**Approach:**

Medical students at USUHS, all of whom must undergo a Mash-like field training exercise, will be studied before, during, and after the experience. Data to be collected include measures of degree of stress experienced and a number of endocrine and immune system activity measures. PIs are particularly interested in how endogenous opioids interact with neutrophil cells, and whether or not this interaction is affected by psychological status.

**Progress:**

Data collection procedures are now ready and will be utilized during the next several training exercises to be executed.

**TITLE:** Immunological Consequences of Social Stratification and Change.

**PRINCIPAL**

**INVESTIGATOR:** Christopher L. Coe  
University of Wisconsin  
Department of Psychology  
(608) 263-3550

**R&T PROJECT CODE:** 442d005    **CONTRACT No:** N0001487K0227

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

The primary objective is to assess how psychological and social factors affect immune competence in the individual. Data will allow determination of which immune measures are most useful for this type of research, and will explore whether or not adrenal and gonadal hormones are important in the mediation of the immune changes observed.

**Approach:**

Various measures of social behavior, hormonal activity, and immune function will be repeated over time. Within subject comparisons will provide information about constancy of the measures, and between subject comparisons will evaluate the effects of various social relationships and changes therein, as operationalized in housing conditions. Stressful challenge will be represented by exposure to an adult male stranger and to a female in heat, as well as by alterations in the normal light/dark cycle.

**Progress:**

Data collection is well under way. While it is still early, pilot analyses indicate that the data contain much that is interesting. Pilot analyses were reported informally at a contractors conference.

**Report:**

Coe, C. L., Lubach, G., Ershler, W. B., & Klopp, R. G. (1988). Effect of early rearing on lymphocyte proliferation responses in juvenile rhesus monkeys. Brain Behavior and Immunity, 2, 276-289.

**TITLE:** Behavior, Immunologic Response, and Upper Respiratory Infection

**PRINCIPAL**

**INVESTIGATOR:** Sheldon Cohen  
Carnegie-Mellon University  
Department of Psychology  
(412) 268-6684

**R&T PROJECT CODE:** 442d007    **CONTRACT No:** N0001488K0063

**CURRENT END DATE:** 31 DEC 1989

**Objective:**

The primary purpose of the proposed research is to determine the role of natural social support systems in individual susceptibility to respiratory infection and related symptomatic behavior. The work will also investigate the role of immunologic function in linking various behavioral measures to disease, and will test two alternative models of the support--illness relationship (social support as a buffer against stress and as a main effect).

**Approach:**

In a prospective design approximately 1,050 healthy subjects are exposed to cold or influenza viruses (or to placebos), then quarantined for 5 days and carefully observed for illness outcomes. Subjects will be characterized on various psychosocial measures and immunologic assays before the trials begin, and these will be analyzed for their power to predict immunologic and illness outcomes.

**Progress:**

Data collection is well under way. A pilot survey of early results was presented at a contractors conference in May 1988.

**TITLE:** Innervation of Immune Organs in Beluga Whales

**PRINCIPAL**

**INVESTIGATOR:** David L. Felten  
University of Rochester  
Department of Neurobiology & Anatomy, Box 603  
(716) 275-8275

**R&T PROJECT CODE:** 442d010    **CONTRACT No:** N0001489J1896

**CURRENT END DATE:** 30 APR 1990

**Objective:**

Obtain and prepare fresh samples of Beluga whale organ systems, for later analysis, so as to better characterize the immune system.

**Approach:**

During a sanctioned hunt, fresh tissue samples from a number of organ systems of the Beluga whale will be obtained and processed for later analysis.

**Progress:**

This contract is new in FY89.

**TITLE:** An Evaluation of the Effects of Stress, Nicotine, Smoking, and Smoking Abstinence on Immune System Functioning

**PRINCIPAL**

**INVESTIGATOR:** Robert A. Jensen  
Southern Illinois University at Carbondale  
Departments of Psychology and Microbiology  
(618) 536-2301

**R&T PROJECT CODE:** 442d009    **CONTRACT No:** N0001489J1968

**CURRENT END DATE:** 31 MAY 1991

**Objective:**

Explore and characterize the effects of smoking and psychological stressors on immunocompetence.

**Approach:**

Perform a series of experiments (a) to determine the effects of nicotine alone and combined with stressors on the immune system functioning of laboratory rats; (b) to compare immune system functioning of smokers and non-smokers under normal and under conditions of psychological stress.

**Progress:**

This contract is new in FY89.

**TITLE:** Vulnerability to Allergic Disorders in Families of  
Children with Behavioral Inhibition

**PRINCIPAL**

**INVESTIGATOR:** Jerome Kagan  
Harvard College  
Department of Psychology  
(617) 495-3870

**R&T PROJECT CODE:** 442d006    **CONTRACT No:** N0001488K0038

**CURRENT END DATE:** 31 MAY 1990

**Objective:**

The main purpose of this research is to determine if there is an association between the presence of the temperamental trait of behavioral inhibition to the unfamiliar in young children and susceptibility to allergic disorders in those children and their close relatives. A second purpose is to determine if an index of social anxiety (an adult analogue of behavioral inhibition) is associated with adult susceptibility to allergy.

**Approach:**

A standard medical interview designed to assess the presence of allergic and other medical disorders will be administered to the parents, grandparents, aunts and uncles of inhibited and uninhibited children. In addition, the mothers of the children will be administered separate interview schedules for the child and the child's siblings. All the adults will be given a standard social anxiety scale to test for an association between susceptibility to allergy and social anxiety.

**Progress:**

This contract is new in FY89.



**TITLE:** Reciprocal Relationships Between the Immune and  
Central Nervous Systems

**PRINCIPAL**

**INVESTIGATOR:** Keith W. Kelley  
University of Illinois  
Laboratory of Immunophysiology  
(217) 333-5141

**R&T PROJECT CODE:** 442d011    **CONTRACT No:** N0001489J1956

**CURRENT END DATE:** 31 MAY 1991

**Objective:**

To determine the effects of the neuroendocrine system on macrophages that secrete monokines which in turn effect the central nervous system to cause a number of adaptive behaviors associated with sickness.

**Approach:**

Conduct a series of experiments to determine whether selected hormones from the pituitary gland affect the synthesis of monokines secreted by activated macrophages, and whether these monokines affect the central nervous system by altering behavior that is conducive to successful elimination of infectious agents.

**Progress:**

This contract is new in FY89.

**TITLE:** Stress, Coping, and Illness

**PRINCIPAL**

**INVESTIGATOR:** Sandra M. Levy  
University of Pittsburgh  
Western Psychiatric Institute  
(412) 647-6351

**R&T PROJECT CODE:** 442d003    **CONTRACT No:** N0001487K0224

**CURRENT END DATE:** 31 OCT 1989

**Objective:**

(1) To relate stressful life events to lymphocyte alteration and to incidence of infectious illness; (2) to explore intermediate links in these relationships (psychological and biological).

**Approach:**

This is a prospective study in which base-line measures will be followed by repeated measures, with analysis of co-variation over time. Measures include: daily stressors, mood, coping style, personality, and health outcomes, as well as a number of neuroimmunological assays.

**Progress:**

This project is still in the data collection phase. Over 70 subjects have now been recruited, baseline data are available on most of these and follow-up data collection is under way.

**TITLE:** Mood, Immunocompetence and Illness

**PRINCIPAL**

**INVESTIGATOR:** Lester Luborsky  
University of Pennsylvania  
Dept. of Psychiatry Research Laboratories  
(215) 662-2822

**R&T PROJECT CODE:** 442d004    **CONTRACT No:** N0001487K0498

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

(1) To explore the degree of interrelationship of measures of mood, immune function and illness on a sample of cyclothymic subjects assessed longitudinally. (2) to explore factors that mediate the interrelationships among these measures, with special attention to endocrine and cognitive factors.

**Approach:**

The research protocol involves within-subject longitudinal recurrent measurement of mood, immunocompetence, and illness, using each subject as his or her own control. Recurrent measurement will also be made of possible endocrine and cognitive mediating factors. Multivariate analyses will identify significant interrelationships among these data.

**Progress:**

Recruitment of subjects is well under way, and data collection has begun. A quasi-meta-analysis of literature relating psychological factors to different immune measures is being carried out.

**MANPOWER, PERSONNEL AND  
TRAINING RESEARCH AND  
DEVELOPMENT PROGRAM**

233/234

**TITLE:** Forecasting Transformational Leadership

**PRINCIPAL**

**INVESTIGATOR:** Bernard M. Bass  
State University of New York at Binghamton  
Center for Leadership Studies  
(607) 777-4362

**R&T PROJECT CODE:** 4428008    **CONTRACT No:** N0001487K0434

**CURRENT END DATE:** 31 AUG 1989

**Objective:**

To establish the predictive validity of a model of transformational leadership that relates to the future success of Naval Academy graduates. The investigation studies the precursors of transformational-leadership behavior, and the impact of such behavior on the effort, satisfaction, effectiveness, and leadership performance, of subordinates.

**Approach:**

A group of 300 Naval Academy graduates described themselves using a multifactor leadership questionnaire; and subordinates also described those same individuals using the same questionnaire. Additional information was obtained from the NPRDC longitudinal officer data-base, fitness reports, and Naval Academy performance records.

**Progress:**

Analyses provided an integrative review of the literature, the development of a general model of transformational leadership in a large sample of Naval officers, a test of the greater effectiveness of Naval officers who exercise transformational leadership as seen by their superiors and their subordinates, the extra work-effort and satisfaction reported by subordinates under transformational leadership, a better fit of self-described leadership behavior with superior's ratings of performance, and a confirmation of the effectiveness of transformational leadership when employed by Naval Academy midshipmen who were squad leaders.

**Report:**

Atwater, L., & Yammarino, F. J. (1989). Personal attributes as predictors of military leadership: A study of midshipman leaders at USNA (Tech. Rep. ONR-TR-7). Binghamton, NY: SUNY at Binghamton, Center for Leadership Studies.

**TITLE:** Team Evolution and Maturation

**PRINCIPAL**

**INVESTIGATOR:** Albert S. Glickman  
Old Dominion University  
Department of Psychology  
(804) 683-4240

**R&T PROJECT CODE:** 4423005    **CONTRACT No:** N0001486K0472

**CURRENT END DATE:** 15 DEC 1988

**Objective:**

To delineate the process variables that comprise teamwork, develop a set of instruments to measure those variables, increase the understanding of how teamwork develops during the course of training, develop ways to diagnose, correct, and enhance team performance, and to examine the generalizability of the findings.

**Approach:**

To refine and validate a longitudinal model of team evolution and maturation for trainees and instructors at Naval schools for gunfire support, anti-submarine warfare, and guided missiles. To construct and validate instruments for measurement of training behaviors. Identify critical dimensions of team behavior. Design intervention strategies for team development.

**Progress:**

A recognizable pattern of team evolution and maturation was observed. The creation of a cohesive, motivated and effective unit required the acquisition of specific teamwork knowledge and skills that had to be recognized by team leaders and instructors, and imparted by them to the trainees. Cost-effective intervention strategies to achieve those goals were identified.

**Report:**

Glickman, A. S., & Zimmer, S. (1989). Team evolution and maturation: Final Report. Norfolk, VA: Old Dominion University, Department of Psychology. AD #A206 914.

**TITLE:** Using Artificial Intelligence to Aid in the  
Development of Causal Models

**PRINCIPAL**

**INVESTIGATOR:** Clark Glymour  
Carnegie-Mellon University  
Department of Philosophy  
(412) 268-8460

**R&T PROJECT CODE:** 4428021    **CONTRACT No:** N0001489J1964

**CURRENT END DATE:** 31 MAR 1990

**Objective:**

The objective is to deliver a practical AI tool that can be used in Navy manpower studies to identify alternative explanatory causal models for non-experimental data.

**Approach:**

The researchers will accomplish their technical objective through further development and testing of their pilot AI system, TETRAD II. This process will involve specific refinements of the pilot system, including addition of an automatic translation capability for use with LISREL, improvement of the user interface, improvement in the construction of initial models, addition of a capability to construct path models, and improvement in search efficiency. Monte Carlo simulations will be used to test effectiveness.

**Progress:**

This contract is new in FY89.

**TITLE:** Navy Training: Effectiveness of Team Training

**PRINCIPAL**

**INVESTIGATOR:** David W. Johnson  
University of Minnesota  
Cooperative Learning Center  
(612) 624-7031

**R&T PROJECT CODE:** 4428002    **CONTRACT No:** N0001487K0218

**CURRENT END DATE:** 14 NOV 1988

**Objective:**

There is strong basic-science evidence that team learning, compared with competitive and individualistic learning, promotes higher achievement, more analytical and higher-level reasoning, greater motivation to learn, and greater commitment to organizational goals. A series of exploratory experiments is implemented to explore those effects in Naval teams.

**Approach:**

Field and experimental methods are employed to examine team learning within Naval training programs. Trainees are randomly assigned to experimental conditions (stratified by ability, ethnic membership, and sex) while instructors are rotated across those conditions. Observational, as well as self-report measures, are taken of the dependent variables.

**Progress:**

Two studies investigated the impact of cooperative team learning, compared with traditional Navy instruction, on the ability to master technical information and use it to perform a complex job. The participants were air traffic control trainees engaged in the study of charts and publications. Results demonstrated that cooperative-team learning lead to greater learning success, more effort to learn, enhanced ability to perform job functions, zero failure rate, better esprit de corps, and more positive perception of instructors.

**Report:**

Johnson, D. W., & Johnson, R. T. (1988). Impact of cooperative-team learning on performance and retention of navy air-traffic controller trainees (Tech. Report). Minneapolis, MN: University of Minnesota.



**TITLE:** Analysis of the Organization of Lexical Memory

**PRINCIPAL**

**INVESTIGATOR:** George A. Miller  
Princeton University  
Department of Psychology  
(609) 452-5973

**R&T PROJECT CODE:** 442c026    **CONTRACT No:** N0001486K0492

**CURRENT END DATE:** 28 FEB 1989

**Objective:**

The objective is to develop a novel kind of electronic lexical reference work, an augmented thesaurus, that is built upon a model of human lexical memory, in order to facilitate tasks in which the relationships of word meanings are important: design of technical and instructional documents, reading and use of such documents, and natural language computer interfaces.

**Approach:**

A computer simulation of human lexical memory is being constructed. A master list of words is being used to simulate phonological access. Lexical concepts are represented as synonym sets. These lexical concepts are being extensively interconnected by networks of meaning relationships: opposition of meaning, part-whole relations, subordination relations, etc.

**Progress:**

As of September 1988, 9,359 noun synonym sets have been entered into the database and 1,661 verb synonym sets. Entry of the adjectives is essentially complete with 10,136 synonym sets including over 50,000 lexical tokens. Explorations of the antonym relationships resulted in defining both an antonym relation between specific words and a more general relation of opposition of meaning. Experiments have been done which tend to confirm the psychological validity of this novel semantic structuring. Word entry continues with emphasis upon special military word senses. Interfaces to Wordnet have been developed and the files are now in ASCII format and the data access code is in C, to promote portability of the software to diverse systems.

**TITLE:** Computers for Knowledge Acquisition and Integration Studies

**PRINCIPAL**

**INVESTIGATOR:** George A. Miller  
Princeton University  
Department of Psychology  
(609) 452-5973

**R&T PROJECT CODE:** dipn230    **CONTRACT No:** N0001489J1247

**CURRENT END DATE:** 30 NOV 1989

**Objective:**

The DOD Defense-University Research Instrumentation Program was designed to improve the capabilities of U.S. universities to conduct DOD-relevant research by supporting the purchase of major equipment critical to the conduct of that research. This effort helps purchase research in the computer simulation of the structure of human semantic memory as a basis for more linguistically sophisticated human-computer interaction in diverse applications, including text-critiquing in a system of aids to designers of instructional materials (AIM) under development at NPRDC.

**Approach:**

Diverse linguistic and psycholinguistic evidence is being drawn upon to suggest the appropriate structure for a computer simulation of the structure of human semantic memory that represents a large proportion of the lexicon of English that is in common use, especially in texts dealing with Naval and other military instructional topics. The present equipment will support the use of sophisticated programming environments that will facilitate the construction and verification of this lexical database. Another contract provides support for the construction of the lexical database and for experimentation on its effective use.

**Progress:**

This contract is new in FY89.

**Outside Funding:**

This award was supported by the Defense-University Research Instrumentation Program.

**TITLE:** Artificial Intelligence Research in Navy Personnel Management

**PRINCIPAL**

**INVESTIGATOR:** Tim Niblett  
The Turing Institute  
(041) 552-6400

**R&T PROJECT CODE:** 4428003     **CONTRACT No:** N0001485J1243

**CURRENT END DATE:** 28 FEB 1990

**Objective:**

This project is exploring innovative techniques for exploring, building, maintaining, and explaining complicated network transshipment programs like the Navy's Enlisted Personnel Allocation and Nomination System (EPANS).

**Approach:**

The approach being explored in this work is to provide a Prolog front end for a complicated Fortran-coded optimization program. An interesting feature of this approach is that investigators are not building a compiler. Instead, they are using a hypertext-like idea. Unlike a conventional hypertext link, however, their links are "intelligent"; controlled by the Prolog specification.

**Progress:**

A prototype front end for the Navy's EPANS system has been developed which facilitates system maintenance and the exploration of alternative models. Yet to be completed are (a) reciprocal links between the Fortran and Prolog code needed for improved explanation, (b) the graphics interface for the schooling problem, and (c) on-line documentation. In addition an improved user interface based upon an adaptation of Hypernews is under development.

**TITLE:** EAM: Scientific Consultant

**PRINCIPAL**

**INVESTIGATOR:** Wallace Sinaiko  
Smithsonian Institution  
(202) 357-1829

**R&T PROJECT CODE:** 4428032    **CONTRACT No:** N0001489C0093

**CURRENT END DATE:** 30 APR 1991

**Objective:**

This contract provides for short-term research, expert consultation, working groups, symposia and conferences, to supplement contract research programs in cognitive and neural sciences. It provides quick reaction responses to research problems associated with the human element in naval operations.

**Approach:**

Continuing support to the programs of the ONR Manpower R&D Committee is provided in such areas as computerized adaptive testing, human resources accounting, attrition, and training.

**Progress:**

The contractor has continued to provide necessary support for the biweekly meetings of the OCNR Manpower R&D Committee. During the past year he organized, conducted, and published the outcome of a major conference on reserve force manpower issues, and continued his chairmanship of an international panel of military manpower researchers which conducts collaborative research on training matters of concern to the Navy.

**TITLE:** Response Latency Measures for Biographical Inventories

**PRINCIPAL**

**INVESTIGATOR:** Larry J. Stricker  
Educational Testing Service  
(609) 734-5554

**R&T PROJECT CODE:** 4428019    **CONTRACT No:** N0001489K0072

**CURRENT END DATE:** 31 AUG 1990

**Objective:**

This research is examining the viability of increasing the validity of the Navy's Armed Services Adaptability Profile (ASAP) by supplementing response choice with response time. The criterion will be 180-day attrition.

**Approach:**

The Armed Services Adaptability Profile (ASAP) will be computer-administered to Navy recruits. Response time data will be collected and response-time measures derived. The comparative validity of these measures vis-a-vis the regular ASAP score, as well as their incremental validity when combined with the regular score will be examined in regression analyses. The impacts of a variety of extraneous response-time determinants will also be examined.

**Progress:**

This contract is new in FY89.

**TITLE:** Self-Improving Instructional Planners for Intelligent Tutoring Systems

**PRINCIPAL**

**INVESTIGATOR:** Perry Thorndyke  
FMC Corporation  
Artificial Intelligence Laboratory  
(408) 289-3112

**R&T PROJECT CODE:** 442C024    **CONTRACT No:** N0001486C0487

**CURRENT END DATE:** 31 OCT 1989

**Objective:**

To develop a generalized architecture for a self-improving instructional planner that develops and executes plans, and improves its planning behavior based on student responses to tutoring.

**Approach:**

Knowledge-engineering techniques are used to build a library of domain knowledge that represents an explicit theory of teaching and an explicit theory of improving instructor's performance. Experimental evaluations of the self-improving instructional planner are used to refine the architecture. An AI "Blackboard" architecture is being used. This contract involves programming the instructional planning module and does not involve actual instructional experiments with students.

**Progress:**

A generalized blackboard architecture was adapted to the requirements of an instructional planner and a prototype instructional planning architecture was implemented. Operation and trouble-shooting of the 25mm weapon for the Bradley personnel carrier was the test-bed application explored, and instructional planning behavior was reverse-engineered from human-produced instruction. Knowledge sources that represent several common instructional strategies were programmed.

# INDEX

## CONTRACTORS

- Advanced Resource Development Corporation, 97
- Albert Einstein College of Medicine, 168
- American College Testing Program, 54
- Arizona State University, 84
- BBN Laboratories, Inc., 183
- Brown University, 95, 138, 160
- CHI Systems, Inc., 129
- California Institute of Technology, 70, 85, 135, 144, 146, 182
- California-Berkeley, University of, 22
- California-Irvine, University of, 20, 69, 72, 147, 148, 166, 180, 190, 191
- California-Los Angeles, University of, 13, 107
- California-Riverside, University of, 215
- California-San Diego, University of, 67, 68, 74, 142, 153, 164, 165, 204
- California-San Francisco, University of, 179
- California-Santa Barbara, University of, 114
- California-Santa Cruz, University of, 209, 217
- Carnegie-Mellon University, 4, 7, 25, 28, 43, 125, 225, 237
- Catholic University of America, 92
- Chicago, University of, 18, 19, 181
- Cold Spring Harbor Laboratory, 110
- Colorado, University of, 31
- Connecticut, University of, 123
- Cornell University, 38, 200
- Dartmouth College and Medical School, 5
- Decision Science Consortium, Inc., 98
- Defense Group Inc., 175
- District of Columbia, University of, 39, 40
- Duke University, 21, 73
- Educational Testing Service, 48, 52, 243
- Emory University, 10
- Environmental Research Institute of Michigan, 206
- FMC Corporation, 244
- Florida Atlantic University, 113
- Florida, University of, 94
- General Dynamics Corporation, 185
- George Mason University, 35, 89
- George Washington University, 78
- Gordon Research Conference, 198
- Guelph, University of, 211
- Harvard University, 8, 64, 177, 228
- Hawaii, University of, 212, 216
- Illinois Institute of Technology, 30
- Illinois-Chicago, University of, 47, 124
- Illinois-Urbana/Champaign, University of, 15, 44, 50, 51, 56, 58, 59, 71, 201, 229
- Institute for Research on Learning, 29
- Iowa, University of, 60
- Johns Hopkins University, 9, 83, 108, 109, 173
- Kansas State University, 210
- Loral Defense Systems - Akron, 171
- Marine Biological Laboratory, 143

Massachusetts Institute of Technology, 66, 75, 105, 106, 111, 151, 172  
 Massachusetts, University of, 133  
 Maxim Technologies, Inc., 99, 189  
 Memphis State University, 16  
 Michigan, University of, 32, 120, 202  
 Microelectronics and Computer Technology Corp., 178  
 Minnesota, University of, 3, 167, 238  
  
 National Academy of Sciences, 65, 101, 102, 127  
 National Aeronautics and Space Administration, 100  
 Naval Ocean Systems Center, 96, 213, 214  
 Naval Submarine Medical Research Laboratory, 91  
 Naval Underwater Systems Center, 119, 176  
 Navy Personnel R&D Center, 57, 128  
 Netrologic, Inc., 90  
 Neurosciences Research Foundation, Inc., 141  
 New Hampshire, University of, 150  
 New York, State University of, 235  
 New York University, 63, 81, 220  
 Northeastern Ohio University, 154  
 Northwestern University, 145, 162  
  
 Old Dominion University, 236  
 Oregon State University, 218  
 Oregon, University of, 77, 82, 112, 188  
  
 Pennsylvania, University of, 174, 231  
 Pittsburgh, University of, 33, 36, 37, 79, 134, 230  
 Portland State University, 53  
 Princeton University, 197, 239, 240  
 Puerto Rico, University of, 203  
  
 R&D Associates, 156  
 Raytheon Company, 184  
 Rochester, University of, 26, 27, 226  
 Rutgers University, 126  
  
 Salk Institute, The, 152  
 San Diego State University, 34  
 Science Applications International Corporation, 140, 186  
 Search Technology, Inc., 122  
 Smithsonian Institution, 242  
 Southern California, University of, 42, 155, 161  
 Southern Illinois University at Carbondale, 14, 227  
 Stanford University, 17, 159  
 System Planning Corporation, 137  
  
 Technical University of Denmark, 139  
 Temple University, 121  
 Tennessee, University of, 55  
 Texas A & I University, 149  
 Thatcher Jones Associates, Inc., 49  
 Tracor Applied Sciences, Inc., 192  
 Turing Institute, The, 241  
  
 Uniformed Services University of The Health Sciences, 223  
  
 Virginia, University of, 163  
  
 Washington University, 76, 80, 187  
 Washington, University of, 6, 199  
 Wisconsin, University of, 93, 224  
 Woods Hole Oceanographic Institution, 219  
  
 Yale University, 41, 115, 136, 195, 196, 205



# INDEX

## PRINCIPAL INVESTIGATORS

- |                   |                        |                      |
|-------------------|------------------------|----------------------|
| Ackerman, 3       | Gage, 142              | Klatzky, 114         |
| Adams, 171        | Gardner, 200           | Kleinman, 123        |
| Anderson, J., 25  | Gazzaniga, 5           | Koch, 70, 146        |
| Anderson, R., 172 | Gentner, 15            | Kornblum, 202        |
| Aston-Jones, 63   | Georgopoulos, 108, 109 | Kosslyn, 8           |
| Atkeson, 105      | Geraci, 211            | Kramer, 71           |
| Baker, 13         | Gerstein, 174          | La Berge, 72         |
| Ballas, 89        | Gibbons, 47            | LaMotte, 115         |
| Barchas, 159      | Glickman, 236          | Lesgold, 33          |
| Barto, 133        | Glymour, 237           | Levine, 50, 51       |
| Bass, 235         | Gold, 163              | Levy, 230            |
| Baum, 223         | Graesser, 16           | Lisberger, 179       |
| Bear, 160         | Greeno, 17             | Lockhead, 73         |
| Berger, 134       | Greenough, 201         | Luborsky, 231        |
| Bever, 26, 27     | Greenwood, 90          | Lugo-Garcia, 203     |
| Birnbaum, 41      | Grover, 175            | Lutfi, 93            |
| Bizzi, 106        | Groves, 164            | Lynch, 147, 148, 180 |
| Blasdel, 64       |                        |                      |
| Bower, 135        | Haley 176              | Margoliash, 181      |
| Brown, 136, 195   | Halvorson, 143         | Marshall, 34         |
| Brownell, 173     | Hammond, 18            | McGaugh, 166         |
|                   | Hanna, 91              | McKhann, 9           |
| Cabral, 119       | Herman, 212            | McLauchlan, 149      |
| Carew, 196        | Hildreth, 66           | Mead, 182            |
| Carpenter, 28     | Hillyard, 67, 68       | Messing, 167         |
| Chambers, 161     | Hockfield, 110         | Michalski, 35        |
| Chawla, 137       | Hoffman, 69            | Middlebrooks, 94     |
| Clancey, 29       | Hogarth, 19            | Miller, G., 239, 240 |
| Clark, 197        | Hohenberger, 121       | Miller, T., 150      |
| Coe, 224          | Holland, 48            | Mislevy, 52          |
| Cohen, 225        | Hollerbach, 111        | Moher, 124           |
| Cooper, 138       | Hopfield, 144          | Montana, 183         |
| Costa, 209        | Houk, 145              | Moskal, 168          |
| Cotterill, 139    | Howard, 92             |                      |
| Cruickshank, 198  | Hubel, 177             | Nachtigall, 213, 214 |
|                   | Hunt, 6                | Newell, 125          |
| Davidson, 140     |                        | Niblett, 241         |
| Disterhoft, 162   | Jensen, 227            | Norris, 215          |
|                   | John, 7                |                      |
| Ebert-Flattau, 65 | Johnson, D., 238       | Ohlsson, 36          |
| Edelman, 141      | Johnson, W., 122       | Pashler, 74          |
| Elkerton, 120     | Jones, 49              | Paulson, 53          |
| Evans, 30         |                        | Payne, 21            |
|                   | Kagan, 228             | Pirolli, 22          |
| Farah, 4          | Karten, 165            | Poggio, 75, 151      |
| Felten, 226       | Keele, 112             | Posner, 76, 77       |
| Feltovich, 14     | Keeler, 178            |                      |
| Fenwick, 210      | Kelley, 229            |                      |
| Fetz, 199         | Kelso, 113             |                      |
| Fox, 31           | Kibler, 20             |                      |
| Fuster, 107       | Kieras, 32             |                      |

Reckase, 54  
Robertson, 126  
Roitblat, 216  
Rothblat, 78  
  
Samejima, 55  
Schneider, 79  
Schofield, 37  
Schusterman, 217  
Segre, 38  
Sejnowski, 152  
Selverston, 204  
Shepherd, 205  
Shulman, 80  
Siegel, 39, 40  
Simmons, A., 184  
Simmons, J., 95  
Simpson, 185  
Sinaiko, 242  
Smith, 218  
Solinsky, 186

Speidel, 96  
Sperling, 81  
Squire, 153  
Steele, 97  
Stevens, 82  
Stout, 56  
Stricker, 243  
Suga, 187  
Sympson, 57  
  
Takahashi, 188  
Tatsuoka, 58, 59  
Teyler, 154  
Thompson, 155  
Thorndyke, 244  
Tolcott, 98  
Towne, 42  
Tusa, 83  
Tyack, 219  
  
Uttal, 84

Van Cott, 127  
Van Essen, 85  
Van Lehn, 43  
Vogl, 206  
  
Wang, 60  
Weaver, 99, 189  
Weinberger, 190,  
191  
Wenzel, 100  
Whitcomb, 101, 102  
Whiteley, 192  
Wilensky, 156  
Wilkins, 44  
Williams, 128  
Williamson, 220  
Winograd, 10  
  
Zachary, 129

# INDEX

## R&T PROJECT CODES

400o041, 97	4424218, 115	4426614, 217
400o042, 90	4424219, 69	4426637, 164
400o043, 99	4424220, 110	4426640, 201
400x038, 70	4424221, 81	4426700, 219
400x053, 66	4424223, 113	4426701, 210
414p006, 182	4424224, 108	4426702, 209
433g008, 44	4424226, 93	4426703, 218
433g017, 38	4424227, 94	4426704, 215
4411018, 167	4424228, 71	4426706, 211
4421546, 50	4424229, 80	4426707, 216
4421548, 56	4424230, 128	4426708, 220
4421549, 55	4424231, 73	4426709, 213
4421550, 53	4424232, 68	4426750, 159
4421551, 48	4424233, 77	4426802, 112
4421552, 52	4424235, 100	4426803, 144
4421553, 47	4424236, 96	4426805, 190
4421554, 57	4424238, 121	4426806, 196
4421555, 60	4424901, 79	4426812, 187
4421556, 54	4425063, 21	4426815, 166
4421557, 58	4425080, 19	4426817, 134
4422538, 6	4425083, 85	4426820, 197
4422541, 59	4425800, 107	4426822, 152
4422543, 3	4426001, 155	4426825, 174
4422547, 14	4426016, 142	4426830, 138
4422548, 16	4426017, 154	4426900, 214
4422549, 17	4426019, 148	4428002, 238
4422550, 22	4426021, 200	4428003, 241
4422551, 8	4426023, 153	4428007, 49
4422552, 40	4426124, 102	4428008, 235
4422553, 4	4426125, 65	4428011, 42
4422554, 30	4426126, 145	4428016, 27
4422555, 10	4426128, 204	4428017, 28
4422556, 7	4426129, 141	4428018, 122
4422557, 5	4426131, 165	4428019, 243
4422558, 9	4426132, 206	4428020, 51
4423005, 236	4426133, 168	4428021, 237
4424167, 127	4426134, 162	4428032, 242
4424200, 114	4426136, 135	4429005, 125
4424202, 95	4426137, 160	4429006, 124
4424203, 126	4426140, 163	4429007, 129
4424204, 101	4426150, 198	4429008, 120
4424205, 89	4426200, 136	4429010, 123
4424206, 82	4426201, 146	4429011, 84
4424207, 91	4426205, 203	4429012, 98
4424208, 72	4426300, 199	4429013, 119
4424210, 78	4426310, 202	442a524, 33
4424211, 83	4426500, 188	442a554, 76
4424212, 74	4426501, 181	442c006, 20
4424213, 92	4426556, 67	442c007, 41
4424215, 111	4426559, 63	442c010, 34
4424216, 106	4426600, 139	442c013, 37
4424217, 105	4426613, 212	442c017, 31

442c022, 13	442f006, 35	a44d004, 183
442c024, 244	442f007, 15	a44e001, 151
442c026, 239	442f008, 36	a44e002, 150
442c028, 29	442g002, 75	a44e003, 178
442d003, 230	442g003, 177	a44e004, 191
442d004, 231	442g004, 172	a44e005, 195
442d005, 224	442g005, 64	a44e006, 133
442d006, 228	442h001, 205	a44e007, 180
442d007, 225	442h002, 176	a44f001, 137
442d008, 223	442h003, 161	a44f003, 140
442d009, 227	442h004, 143	a44f004, 156
442d010, 226	442h010, 147	a44f006, 175
442d011, 229	a44b001, 186	a44f007, 179
442f001, 43	a44b002, 171	dipn128, 173
442f002, 32	a44c001, 184	dipn130, 39
442f003, 18	a44d001, 192	dipn131, 149
442f004, 25	a44d002, 189	dipn230, 240
442f005, 26	a44d003, 185	dipn231, 109